Mu'tah University
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Mathematical Model of Normal and Abnormal Heart of Humans.

By
Mahmmoud Awad Odeh Alniamat

Supervisor
Dr. Khaled Nawafleh

Co. Supervisor
Dr. Sultan Almaasfeh

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استكمالاً لمتطلبات الحصول على درجة الماجستير في **الفيزياء.**

القسم: الفيزياء.

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أ.د. خالد عيسى النوافله		٢٠١٥/١٢/٢٨	مشرفاً ورئيسا
د. سلطان عبدالمجيد المعاسفه		٢٠١٥/١٢/٢٨	مشرفا مساعدا
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د. عبدالرحيم أحمد الجمل		٢٠١٥/١٢/٢٨	عضواً

عميد الدراسات العليا

د. محمد المحاسنة

MUTAH-KARAK-JORDAN
Postal Code: 61710
TEL :03/2372380-99
Ext. 5328-5330
FAX:03/ 2375694
e-mail: dgs@mutah.edu.jo sedgs@mutah.edu.jo
http://www.mutah.edu.jo/gradest/derasat.htm

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فاكس 375694 ٠٣/٢
البريد الالكتروني
الصفحة الالكترونية

Dedication

I dedicate this work to all of whom left us and we memorize fresh deeds in our mind, to the late my father and my uncle.
My brothers Mohammad and Ahmad…….
My beloved mother…..My sisters …
And my relatives and other friends.

Mahmmoud Awad Odeh Alniamat

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Mahmmoud Awad Odeh Alniamat

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List of Abbreviations

(CF).	Color Flow
(PRF	High Pulsed – Range Frequency
TM	Color Time Motion
CFM	Color Flow Mapping
SP	Spectral analysis
TM	Time –Motion mode
2D	Two-Dimensional mode
CW	Continuous waves
(PW	Pulsed wave
SVC	superior vena cava
IVC	inferior vena cava
η	efficiency
CFD	computational fluid dynamics
Ees	elastance
SW	stroke work
PVR	pressure-volume relationship
RV-PC	right ventricular-pulmonary circulation
mW	milliWatts
RVOT	right ventricle outflow tract
PS	Pulmonary stenosis
PV	pulmonary valve
AoV	aortic valve
LA	left atrium
LV	semilunar valves
SI	left ventricular
AV	atrioventricular valves
r	radius
S	speed
A	area
Q	flow
dV	the change of volume
dt	the change of time
dW	the change of work done
P	power
ρ	pressure
avg	average
sum	summation
st.d	standard deviation
var	variance
R	correlation factor
m/s	meter/second

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Abstract

Mathematical Model of Normal and Abnormal Heart of Humans.

Mahmmoud Awad Odeh Alniamat
Mutah University, 2015

This project was performed using Doppler echocardiography instrument. The heart was the analogue of a pump ,measurements were taken on three parts ,left and right side ,and the heart as a whole ,forty seven individuals were subjected to echocardiographic test ;five of them were abnormals (heart disordered) .

Measurements were taken from the echocardiographic test to calculate power ,flow and efficiency for the parts of the heart.
Using Microsoft excel ,results were tabulated and figures were drawn to study the behavior of the three parts per one second ,R correlation factor with best fit trend line and mathematical equation were fixed on all figures.

All figures of normal cases showed a linear increase with high value of R in comparing power versus flow for all parts but when comparing power versus power and flow versus flow in using input and output of blood ,they gave nearly a constant trend with very small value of R but for efficiencies of all parts their trends were exponential with high values of R.

Finally when comparing abnormals their trends were random with higher scales for comparing flow versus power constancy was disappeared when comparing flow versus flow and power versus power (power gave linear increase ,while flow gave linear decrease). But for efficiencies all figures gave the exponential trend for normal and abnormal but with different scales.

This means that mathematical models taken by Excel can be considered to compare whether case may be normal or abnormal.

الملخص

نموذج رياضي للقب للأصحاء وغير الأصحاء

محمود عواد النعيمات

جامعة مؤتة، 2015

استخدم لهذه الدراسة جهاز صدى القلب Doppler، جزئت الدراسة الى ثلاث مجموعات جهة اليمين واليسار وللقلب ككل وتم دراسة سبع واربعون حالة منهم خمس غير اصحاء وباستخدام برمجية اكسل جدولت النتائج ورسمت الاشكال مثبت عليها معادلة افضل خط مع معادلة الارتباط R ومعادلة رياضية تخص السلوك الرياضي على كل شكل.

جميع الاشكال للأصحاء اعطت زيادة خطية طردية عند المقارنة بين التدفق والقدرة في جميع الاحوال وبمعامل ارتباط عالي اما عند مقارنة القدرة مع القدرة والتدفق مع التدفق لدم الدم الداخل والخارج عبر كل جزء كان التغاير ثابت وبمعامل ارتباط صغير جدا، وسلوك الكفاءة كان اسيا وبمعامل ارتباط عالي جدا.

وعند مقارنة غير الاصحاء من خلال مقارنة القدرة مع التدفق كان التغاير عشوائي وقيم معامل الارتباط متغايرة، وعند القدرة مع القدرة والتدفق مع التدفق كانت الثبوتية في التغاير بل اصبحت زيادة خطية في القدرة وانحدار خطي في التدفق وبمعامل ارتباط اعلى مما كان عليه في الاصحاء.

اما سلوك الكفاءة فكان اسيا لجميع الحالات الاصحاء وغير الاصحاء لكن التدرج اختلف واصبح اعلى في حالة غير الاصحاء.

وعليه يمكن اعتبار هذه النموذجة الرياضية قادرة على تبيان اذا كانت الحالة طبيعية او غير ذلك.

Chapter One
Introduction

1.1 Introduction

A pump is a mechanical engine which used to raise fluid to high buildings ,and to study variables to see whether this engine is able to raise fluid to a certain height ;variables are as power or energy that has to be dissipated for this job during a certain period of time ,another variable as flow.

Similarly heart of human is the pump which pumps blood to higher organs like head, neck and other parts and down to lower limbs. Which means that pushes blood to head and feet then withdraws blood from feet and head toward the heart.

The Human being as a whole is a very complicated system, because it consists of many systems that are working with each other. In this project we have to study cardiovascular system which plays the important role in the life of the human being . Muscular exercise requires a higher energy output. The corresponding increased need of oxygen and nutrients is covered by increased demands on the cardiac system.(Hayano and Yasuma, 2003). At the same time the blood distribution changes, more blood is transported to the exercising muscle, less to the internal organs (Marieb and Hoehn, 2007). The amount of oxygen to be taken up in the lungs and transported by the cardiovascular system depends on the cardiac output, a product of the heart rate and stroke volume, and on the ateriovenous oxygen difference (Leach and Treacher, 2002). The performance limit of the heart is given by the maximal cardiac output while the capacity for endurance exercise in man on the oxygen uptake over given periods of time (Baicu et al., 2005)

The two parts of the system, one depends on the other so we had to understand well the two constituents of pump system. A great deal of intention was paid to study the heart physical parameters by echocardiography with many systems and at last, a trial was done with a great intention to find correlation between the three parts of the system. (Kasprzak and Iskander, 2007)

1.2 Review in heart functions study:

Many studies were done to study different functions of the heart. Several physical parameters were used either by physicians to diagnose the state of the disease or by the researchers to study and analyze different functions of the heart and to do calculations, these studies are included.

1.2.A-Heart sounds:

All heart sounds are heard either by stethoscope or recorded by phonocardiography. Heart sounds are associated to a movement of the four valves either by opening or closing. Two main sounds are heard, the first one is soft low pitched which associates with the closure of the atrioventricular valves (AV) at the onset of systole, while the second one is louder and associates with the closure of the semilunar valves (SI) at the onset of the diastole (Stevens et al., 2003; Yip et al., 2002), figure (1.1).

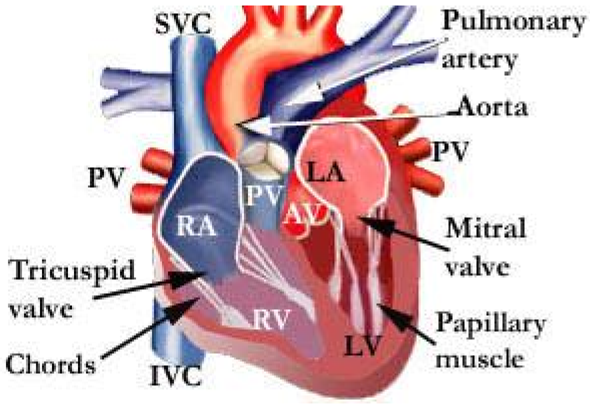


Fig 1.1 The heart with four chambers and valve's.

1.2.B-Heart murmurs:

Three categories of murmurs are known: systolic, diastolic and continuous murmur. A systolic murmur begins with or after the first heart sound; and ends at or before the second heart sound (Dahl et al., 2002). A diastolic murmur begins with or after the second heart sound and ends before the first heart sound. Finally the continuous murmur begins in systole and continues without interruption throughout the time of the second heart sound into all parts of diastole (DeGroff et al., 2001; Yip et al., 2002).

1.3 Types of valves

1.3.1 The mitral valve:

The normal mitral valve consists of 1- valve ring 2-two unequal cusps (leaflet) anterior and posterior linked to each of 3- chordae tendinae and 4- papillary muscles (Guy and Hill, 2012)

Six elements are critical in the normal action of the mitral apparatus. These are the same four points above in addition to LA and LV wall. The leaflets are thick membrane that is trapezoidal with fine irregular edges; they originate from the annulus fibrosis and are attached to the papillary muscle by chordae tendinae which are collagenous stands that when they are tensed contracting the papillary muscles, preventing the cusps from prolapsing into LA during LV systole (Guy and Hill, 2012; Prot et al., 2009)

1.3.2 The pulmonary valve

It's situated in-between the infundibulum and the pulmonary trunk. A fibrous ring through which three attached cusps (leaflets) surrounds the orifice. The three cusps are called right, posterior and anterior cusps. They are semi- lunar in shape and attached by their thickened convex margins to the atrial annulus(Khambadkone et al., 2005), (RV) in systole, the cusps are forced to be opened against the walls of the pulmonary trunk, while in diastole the blood rushes back in, enabling the cusps to come together toward the luminal center so that the free margin coalesces and closes off the lumen

The pulmonary valve cusps are transparent during youth, later in life they tend to be opaque. The pulmonary valve is less tight than that of the aortic valve (AoV), because it has a less tight fibrous ring, thinner cusps and shallower sinuses. Furthermore the retrograde pressure gradient through the pulmonary valve in diastole may not be enough to close the valve as tightly as the aortic valve, so it is normal for healthy subjects to have trivial regurgitation through the pulmonary valve (PV)(Frigiola et al., 2004)

Although many investigators have detected signals suggestive of pulmonary regurgitation in many normal healthy subjects others have not detected any signal (Lancellotti et al., 2010)

1.3.2.1 Main pulmonary valve disorders

In general any valve can either be stenosed or regurgitant but if it is so damaged it can be both stenotic and regurgitant.

Congenital defects are most common caused of organic pulmonary valve disease, reversible functional regurgitation is found as a result of the stretching of the valve ring due to congestive cardiac failure. Rheumatic involvement of the pulmonary valve is infrequent, although it may occur especially in patients with severe rheumatic carditis involving all heart valves (Rodriguez-Roisin et al., 2004)

1.3.2.1.A- Pulmonary stenosis (PS).

Pulmonary stenosis includes a number of conditions in which blood flow from till right heart to the lungs is obstructed. The cardinal features include reduction in pulmonary blood flow, right ventricular hypertrophy and a murmur at the site of obstruction (Tulzer et al., 2002).

The site of obstruction is usually at the pulmonary valve but may occur in the right ventricle outflow tract (RVOT) or in the main pulmonary artery and its branches. These three major types of stenosis may occur individually or in combination. The congenital form is the most common cause of tile pulmonary stenosis (Richards and Garg, 2010).

Rheumatic inflammation of the pulmonary valve is very uncommon and usually associated with involvement of other valves and rarely leads to

serious deformity. The commonest presenting symptom in patients with moderate or severe pulmonary stenosis is dyspnea, mild pulmonary stenosis doesn't cause a significant symptom (Schoof et al., 2006).

1.3.2.1.B--Pulmonary regurgitation PR:

If there is blood regurgitation (comes back) from the pulmonary artery to the right ventricle at diastole, it will represent a volume overload on the right for pumping the blood coming back from the pulmonary artery. The well increase the stroke volume while passing through deformed pulmonary valve, commonly causes turbulence which is noticed by production of pulmonary ejection murmur (Lancellotti et al., 2010).

1.4 Aortic valve :

The central conduit from the heart to the body, the aorta carries oxygenated blood from the left ventricle to the various parts of the body as the left ventricle contracts. Because of the large pressure produced by the left ventricle, the aorta is the largest single blood vessel in the body and is approximately the diameter of the thumb. The aorta proceeds from the left ventricle of the heart through the chest and through the abdomen and ends by dividing into the two common iliac arteries, which continue to the legs (Mueller et al., 2015).

One of the four one-way valves that keep blood moving properly through the various chambers of the heart. The aortic valve, also called a semi-lunar valve, separates the left ventricle from the aorta (Mitchell and Brown, 2014). As the ventricles contract, it opens to allow the oxygenated blood collected in the left ventricle to flow throughout the body. It closes as the ventricles relax, preventing blood from returning to the heart. Valves on the heart’s left side need to withstand much higher pressures than those on the right side; Sometimes they can wear out and leak or become thick and stiff (Tu et al., 2015).

1.4.1Congenital aortic stenosis

this form is provoked by fibrocalcific degeneration in a congenitally deformed aortic valve. The end result of all three processes is the same that is commissure fusion with narrowing of the aortic valve orifice(Reiss et al., 2005). When the degeneration and calcification are severe it may be impossible to determine which of the three forms of the aortic stenosis when it is present. Another common finding in patient with severe aortic stenosis is concentric left ventricular hypertrophy with thickened left ventricular walls typically with chamber of normal or near normal size(Grothues et al., 2002)

1. 4.2 Aortic valve regurgitation:

Aortic regurgitation may result from aortic valve disease or from disease of the aortic root.

Common causes of valvular aortic regurgitation include A) rheumatic aortic insufficiency (always associated with mitral valve disease).

B) infective endocarditis C) congenital deformities and D) aortic valve prolapse(Tsifansky et al., 2010; Webb et al., 2009).

The common causes of aortic regurgitation secondary to disease of the aorta are: Syphilitic aortitis ,Marfan's syndrome , Dissecting aneurysm of the aorta andAnkylosing spondylitis (Homme et al., 2006).

1.4.3 Aortic regurgitation and insufficiency:

Aortic regurgitation is usually due to rheumatic heart disease it may be congenital but the associated lesion such as ventricular septa defect is usually more important. Other causes are hypertension, aortic dissection, endocarditis, Marfan's syndrome, ankylosing spondylitis, (Gornik and Creager, 2008; Homme et al., 2006).

1.5 Previous studies in Echocardiography.

Roberto M. Lang et al,2015 studied the quantification and recommendation for cardiac chamber in adults by echocardiography they needed for updated recommendation to previously guide lines for cardiac chambers quantification. This document provides updated normal values for all four chambers including three dimensional echocardiography and myocardial deformity.

Sandor J. Kovacs 2015, they studied the diastolic function in heart failure and they focused their attention to the diastole in heart failure, the dominant physiologic laws that govern the process of all hearts how all hearts work as a suction pump and therefore the elucidation and characterization of what actually is meant by a diastolic function. Proper measurement of diastolic function requires one to go beyond.

On 2015 Namheon Lee et al the dysfunctional right ventricular-pulmonary circulation (RV-PC) adversely affects the RV myocardial performance resulting in decreased efficiency. Therefore, comprehensive hemodynamic assessment should incorporate changes in RV-PC and energy efficiency for CHD patients.The ventricular pressure-volume relationship (PVR) and other energy-based endpoints derived from PVR, such as stroke work (SW) and ventricular elastance (Ees), can provide a measure of RV performance. However, a detailed explanation of the relationship between RV performance and pulmonary arterial hemodynamics is lacking. More importantly, PVR is impractical for routine longitudinal evaluation in a clinical setting, because it requires invasive catheterization. As an alternative, analytical methods and computational fluid dynamics (CFD) have been used

to compute energy endpoints, such as power loss or energy dissipation, in abnormal physiologies. In this review, we review the causes of RV-PA failure and the limitation of current clinical parameters to quantify RV-PC dysfunction. Then, we describe the advantage of currently available energy-based endpoints and emerging energy endpoints, such as energy loss in the Pas or kinetic energy, obtained from a new non-invasive imaging technique, i.e. 4D phase contrast MR.

Hide Katsu Fukuta and Williams Colittle 2008 they studied the way and the time of filling and contraction of left ventricle in health and disease.

On 2007 Sangita Kapur et al studied The major collateral pathways seen with SVC or IVC obstruction are well described and include the azygoshemiazygos, internal and external mammary, lateral thoracic, and vertebral pathways. In addition, several unusual collateral pathways may be seen with SVC or IVC obstruction; these include systemic-to-pulmonary venous, cavoportal, and intrahepatic collateral pathways. In patients with systemic-to-pulmonary venous collateral vessels, the systemic veins drain directly into the left side of the heart, resulting in a right-to-left shunt. The collateral veins consist of mediastinal connections between the innominate veins and the superior pulmonary veins through bronchial venous plexuses around the airways, hilar vessels, and pleura. The cavoportal collateral pathways consist of collateral formation between the SVC or IVC and a tributary to the portal system.

On 2002 Gerhard Müller-Strahl et al LV and RV flows responded analogously to changes in loading conditions and were in accordance with the Frank-Starling principle. Linearization of parameters derived from the LV and RV function curves showed that the operation of both ventricles was quantitatively similar when unloaded and increasingly dissimilar when loaded. With increasing RV preload, the characteristics of the RV pump function curves changed; however, those of the LV hardly changed. Power, contractility and relaxation data of the ventricles were compared by applying the concept of corresponding afterloads, which showed that these parameters, except for power, had an inconsistent preload and afterload dependence in the LV and RV. Even though LV and RV performances displayed coexisting analogies, quantitative similarities and qualitative dissimilarities, in the case of relaxation, a concept unifying the heterogeneous data set for both ventricles has been developed. The hypothesis may be put forward that the macroscopic relaxation process of the heart muscle runs in parallel with cellular calcium handling.

On 2000 Kluckow M and Evans N studied Other measures included colour Doppler diameters of ductal and atrial shunts, as well as Doppler assessment of shunt direction and velocity, right and left ventricular outputs. Upper body vascular resistance was calculated from mean blood pressure and SVC flow.

Low SVC flow may result from an immature myocardium struggling to adapt to increased extrauterine vascular resistances. Critically low flow occurs when this is compounded by high mean airway pressure and large ductal shunts out of the systemic circulation. Late IVH is strongly associated with these low flow states and occurs as perfusion improves.

A comparison was done by (Gijs Elzinga et al , 1980) when considering pump function of left and right ventricles in isolated ejecting cat hearts in which the natural series arrangement between the two sides of the heart was broken. The relationship between mean ventricular pressure and output obtained by varying the arterial load, the so-called pump function graph, and the mean external power output found at the various load levels, was taken as the basis for the comparison. They also studied the way in which pressures and flow generated by the right ventricle are changed by alterations in resistance and compliance of the loading arterial system, is qualitatively similar to what has been found in a previous study for the left side of the heart, in spite of the structural differences. The right ventricular pump function curve differs from the left ventricular curve in the absolute scale for the mean pressure axis, but if the scale is adjusted appropriately, the two curves look alike. Right ventricular pump function is dependent on the left ventricular contraction mode. The presence of an isovolumic beat on the left side of the heart enhances right ventricular pump function. This is in contrast to the very small effect of the right ventricular contraction pattern on the pump function of the left side of the heart.

On 1976 Wilmer W. et al studied how determine the systemic input impedance, pulsatile pressure and flow were measured in the ascending aorta in 16 human subjects who were undergoing diagnostic cardiac catheterization. Blood flow was measured with a catheter-tip electro-magnetic velocity meter, and pressure with an external transducer connected with the fluid-filled lumen of the catheter. Five subjects were found to have no evidence of cardiovascular disease (group A, mean age 32 ± 2 years, mean aortic pressure 97 ± 4 mm Hg). Seven had clinical and angiographic signs of coronary arterial disease, and mean pressures less than 100 mm Hg (group B, mean age 48 ± 2 years). Four subjects had signs of coronary disease and mean pressures greater than 100 mm Hg (group C, mean age 48 ± 3 year.

External left ventricular work per unit time (hydraulic power) averaged 1715 milliWatts (mW) in group A, 1120 mW in group B, and 2372 mW in group C. Cardiac outputs were within normal limits in all subjects, but tended to be lower in group B than in group C. These results suggest that the subjects of group C were better able to meet the increased energy demands imposed by an abnormally high aortic input impedance.

On 1966 William R et al Pulmonary vascular input impedance and hydraulic power were measured at various heart rates in 29 anesthetized and 5 unanesthetized dogs. Hydraulic power at the pulmonary veno-atrial junction

was measured in 5 dogs. The pulmonary vascular impedance spectrum in the unanesthetized dogs did not differ significantly from that in the anesthetized dogs. Average pulmonary arterial power in the anesthetized dogs was 157 milliWatts (mW), of which 108 mW was associated with mean pressure and flow, and 49 mW with the pulsations around these means. Seventy-eight per cent of this input power was dissipated in passage through the pulmonary bed. Kinetic energy accounted for 7% of the total input power. Because of a steep fall in impedance between zero and 3 cycles/sec, and a rate-dependent change in the harmonic structure of flow pulsations, there was an inverse relationship between heart rate and the input power for a given mean flow, up to 180 beats/min. Pulmonary vascular dimensions and elasticity, which determine impedance, thus embody a mechanism whereby tachycardia can increase pulmonary blood flow as much as 35% with an increase in pulmonary arterial input power of less than 5%, without the intervention of vasomotor activity.

1.6 Aim of study.

To achieve the aim of this study, considering the heart as a mechanical pump, studies must be focused to understand the behavior of heart parts, left side or right side of the heart and finally to the heart as a whole, these parts where blood comes in and out of the parts and through gates that are called valves where flow and speed of blood may be influenced either in health, under exercise or disease.

Chapter two
Materials and Method

2.1 Introduction

To fulfill the aim of this study forty two cases were taken in this thesis to subject an echocardiographic test. Independent variables as time , radius , speed , and pressure were taken to calculate the power and flow for the left side of the heart , the right side of the heart and for the heart as a whole by very simple equations (in fluid mechanics).

2.2 Volunteers

No specific selection was necessary in choosing volunteers, the aim of the project was to establish a method rather than to make a clinical comparative study, according to 42 subjects normals and five subjects abnormals were taken to achieve the aim of study at Al-Hussain Medical City, these were of different heights, weights and ages. They were subjected to an echocardiographic test to see whether they are patients or not.

2.3 Echocardiographic Investigations

Echocardiographic was made for normal and abnormal persons to characterize:

1. Superior vena cava radius , pressure and speed .
2. Inferior vena cava radius , pressure and speed .
3. pulmonary artery radius , pressure and speed .
4. pulmonary veins radius , pressure and speed
5. Aorta radius, pressure and speed.

After taken these independent values for subjects with a constant period of time, each value was used according to equations as (in fluid mechanics)

1.continuity equation which declares that(Cengel and Cimbala 2014)

$Q = A * S$…………………..……………………………….…….2.1

Where A is the area of the artery or vein in m^2 .

S is the speed of the blood in m /s And Q is the flow in m^3/s .

From equation 2.1

$A = \pi r^2$ ……………………………………………………..…2.2

Where r equal the radius of the artery or vein in m.

2. Power equation is taken from (the first law in thermodynamics) (Moran,2014) where

$dW = \rho * dV$…………………………………...……..……2.3

where dW is change in work or dissipated energy for heart muscle in Joule .

ρ is pressure in Pascal

dV is change of volume in m^3 .

when dividing eq2.3 by the dt where dt is change in time (per time), gives power (P).

$$P = dW/dt = \rho * (dV/dt) \quad \ldots\ldots 2.4$$

Which means that P is equal to energy dissipated per unit time in Watt.
Let dt is one second for all cases.
Calculation of efficiency (η) was taken in consideration

$$\eta = \text{output} / \text{input} \quad \ldots\ldots 2.5$$

Where input or output are considered either for power or flow and calculation was done for the three groups of data.(see Appendix B).

2.4 Characteristics of the Ultrasonic System

In Jordan, Al-Hussain Medical center the echocardiography system used during the first forty-two cases was Scanning System Ultrasonic-Vivid Eq (VE93833 - 2012) in QAHI/ECG that is provided with three types of transducers, they could be operating in two wave patterns.

1.Pulsed wave (PW) which includes two frequencies

a) 2.8 MHz

b) 7.5 MHz

They could be used for different purposes .

2. Continuous waves (CW) which works in a single frequency of 2 MHz and used when the pulsed wave is hardly helpful when high velocities are detected causing the aliaising limitation.

The instrument is provided with the capability of producing in the following modes:

A. Two-Dimensional mode (2D).
B. Time –Motion mode (TM) .
C. Spectral analysis (Doppler) (SP) .
D. Color Flow Mapping (CFM) .
E. Color Time Motion (CTM) .

The screen may show the 2D mode with TM mode at the same time , or with the SP mode , while CFM mode could only be displayed with the CTM mode. The opportunity of displayed two modes with an ECG record at the same time can yield a lot of information regarding the accurate diagnosis of diseases.

The facility of showing the ECG on the screen with a cursor to tell in which position or stage the 2D image (whether it's systole or diastole), enables to do a comparison between the two stages and their changes .When the CFM mode is used, ejection of blood from one chamber to another could be displayed .

In addition wall thickness valvular orifice, ventricle contractility, and chamber size could be evaluated accurately.

The 2D mode has several views according to the position of the transducer and its angle, the views are:

1) Parasternal long axis view.
2) Parasternal short axis view.
3) Apical view :
   a) The four-chambers view
   b) The five-chambers view
4) Subcostal view.
5) Suprasternal view.

After using the 2D and TM mode the Doppler Examination is performed which has four deferent types : -

1. Pulse Wave (PW).
2. Continuous Wave(CW).
3. High Pulsed – Range Frequency (PRF).
4. Color Flow (CF).

The instrument has also the capability of saving several of serial pictures and then displaying them in also with motion.

The other property of the system is the capability of magnifying the image twice its normal size.

In all modes there are two moving cursors that could be controlled to take several measurement.

2.5 Manipulation of the probes

The echocardiography examination is performed in privacy. The examination is explained to each patient , then he/she should lie flat on the examination couch/table, sticky patches or electrodes are attached.

The chest and shoulders and connected to electrodes or wires , for recording the electrocardiogram during the test. This helps us to peruse various cardiac events.

A colorless gel is then applied to chest and the echo transducer which is placed on top of it. The subject is asked frequently to change his position on the left or back flat.

The views were obtained as long axis view, short axis view of great vessels, four chambers view and suprasternal and abdominal views in 2D (two dimension) image, color Doppler and pulsed wave Doppler. At the pulmonary value and aortic value levels.

At SVC mid-level , inferior vena cava before imaging the right atrium and right upper pulmonary vein, at four chamber and subcostal view at around 0.5 cm before the left atrium.

All the examination were done by a single way of examination.

All the examination were recorded machine used was Vivid Eq , from GE Healthcare.

Figure (2.1)

Figure(2.1)
Echocardiographic apparatus used in QAH

Electrocardiogram is a type of ultrasound test that used high pitched sound waves that are sent through a device called transducer. It is used for subjects with abnormal heart sounds, enlarged hearts unexplained chest pain or pressure, shortness of breath or irregular heartbeats.

So it can detect cardiomyopathies in general, can genital heart defects.

Diseased or abnormal values, causes the heart failure and the effect of ischemia or regional wall movement of the left ventricle.

2.6 Patient's Form

The form organized to cover a large number of parameters and measurements. It includes, in addition to the personal information like name, age, sex, height, weight and identity number, it included physical parameters which are necessary to complete the echocardiography study requirements.

Some measurements in the from were taken using the TM-mode, like the orifices diameters as the values orifice diameters of the pulmonary and aortic values (the distance between the leaflet of the two valves).

Pulmonary and aortic valve orifice measurements are taken at the period of mid systole. The quality of the echocardiographic image of the two valves could be known either good, poor or none by using TM-mode with 2D-mode echocardiography while from Doppler (SP)-mode the velocity of blood flow and pressure gradient measurements for pulmonary and aortic valves.

Name or number:……..
Age……………. Height……….weight………….

NO.1		Superior v .c	Inferior v .c	P.artey	p.veins	aorta
	Radius					
	speed					
	pressure					
	volume					
	time					
NO.2		Superior v .c	Inferior v .c	P.artey	p.veins	aorta
	Radius					
	speed					
	pressure					
	volume					
	time					
NO.3		Superior v .c	Inferior v .c	P.artey	p.veins	aorta
	Radius					
	speed					
	Pressure					
	Volume					
	Time					
NO.4		Superior v .c	Inferior v .c	P.artey	p.veins	aorta
	Radius					
	speed					
	pressure					
	volume					
	time					
NO.5		Superior v .c	Inferior v .c	P.artey	p.veins	aorta
	Radius					
	speed					
	pressure					
	volume					
	time					
NO.6		Superior v .c	Inferior v .c	P.artey	p.veins	aorta
	Radius					
	speed					
	pressure					
	volume					
	time					

Chapter Three
Results

In investigating the echocardiographic from section (2.3), all important physical parameters were taken in consideration. They are divided into three groups, first group is to indicate values of SVC+IVC and values of pulmonary artery where values of power and flow must be calculated from independent variables as below.

3.1 Measurement of power and flow of the right part of the heart

For the first group, fundamental parameters are taken to build up a comparison between two dependent variables of flow and power from the independent variables of radius. To calculate area, speed to calculate change in volume and flow, and pressure to calculate power or change in dissipated energy per unit time.

Table (3.1.a and b) show values of power and flow calculated for the input of the right side of the heart (the sum of power and flow of superior vena cava + inferior vena cava) with their values of sum , av , var and t-test (see Appendix A)

Table (3.1.a)
The values of superior vena cava(SVC) calculated from their independent values with their conversion to SI units.

N	r (cm)	r(m)	A(m^2)	S(m/s)	ρ (mmHg)	ρ(Pascal)	P(watt)	Q(m^3/s)
1	2.1	0.021	0.001386	0.31	0.11	14.69079	0.006312	0.00043
2	1.8	0.018	0.001018	0.4	0.23	30.71711	0.012512	0.000407
3	2	0.02	0.001257	0.32	0.12	16.02632	0.006447	0.000402
4	2.4	0.024	0.00181	0.32	0.12	16.02632	0.009284	0.000579
5	1.9	0.019	0.001135	0.34	0.55	73.45395	0.028335	0.000386
6	1.5	0.015	0.000707	0.28	0.45	60.09868	0.0119	0.000198
7	1.8	0.018	0.001018	0.2	0.45	60.09868	0.01224	0.000204
8	2.1	0.021	0.001386	0.29	0.13	17.36184	0.006978	0.000402
9	1.8	0.018	0.001018	0.28	0.11	14.69079	0.004189	0.000285
10	1.5	0.015	0.000707	0.28	0.4	53.42105	0.010577	0.000198
11	2	0.02	0.001257	0.28	0.6	80.13158	0.028206	0.000352
12	2.2	0.022	0.001521	0.3	0.48	64.10526	0.029254	0.000456
13	1.8	0.018	0.001018	0.11	0.35	46.74342	0.005236	0.000112
14	1.8	0.018	0.001018	0.25	0.45	60.09868	0.015299	0.000255
15	1.8	0.018	0.001018	0.25	0.31	41.40132	0.01054	0.000255
16	2	0.02	0.001257	0.25	0.31	41.40132	0.013012	0.000314
17	1.8	0.018	0.001018	0.25	0.25	33.38816	0.0085	0.000255
18	1.5	0.015	0.000707	0.2	0.35	46.74342	0.006611	0.000141
19	1.9	0.019	0.001135	0.3	0.35	46.74342	0.01591	0.00034
20	2.2	0.022	0.001521	0.35	0.55	73.45395	0.039107	0.000532
21	2.5	0.025	0.001964	0.25	0.32	42.73684	0.020987	0.000491
22	2.3	0.023	0.001663	0.25	0.33	44.07237	0.018318	0.000416
23	2	0.02	0.001257	0.33	0.41	54.75658	0.022716	0.000415
24	1.5	0.015	0.000707	0.31	0.45	60.09868	0.013174	0.000219
25	2.5	0.025	0.001964	0.22	0.31	41.40132	0.017891	0.000432
26	2	0.02	0.001257	0.3	0.5	66.77632	0.025184	0.000377
27	2.2	0.022	0.001521	0.25	0.32	42.73684	0.016252	0.00038
28	2	0.02	0.001257	0.21	0.51	68.11184	0.017982	0.000264
29	2	0.02	0.001257	0.22	0.32	42.73684	0.01182	0.000277
30	2.2	0.022	0.001521	0.11	0.25	33.38816	0.005587	0.000167
31	2	0.02	0.001257	0.25	0.25	33.38816	0.010493	0.000314
32	2.4	0.024	0.00181	0.35	0.15	20.03289	0.012693	0.000634
33	1.9	0.019	0.001135	0.22	0.35	46.74342	0.011667	0.00025
34	2.2	0.022	0.001521	0.28	0.48	64.10526	0.027304	0.000426
35	1.8	0.018	0.001018	0.21	0.35	46.74342	0.009996	0.000214
36	2	0.02	0.001257	0.27	0.31	41.40132	0.014053	0.000339
37	1.8	0.018	0.001018	0.27	0.39	52.08553	0.01432	0.000275
38	1.5	0.015	0.000707	0.27	0.45	60.09868	0.011475	0.000191
39	2	0.02	0.001257	0.36	0.6	80.13158	0.036265	0.000453
40	1.8	0.018	0.001018	0.3	0.41	54.75658	0.016727	0.000305
41	1.8	0.018	0.001018	0.28	0.39	52.08553	0.014851	0.000285
42	1.2	0.012	0.000453	0.29	0.31	41.40132	0.005434	0.000131

Table (3.1.b)
The values of IVC calculate from their independent values with their conversion to SI units with the sum of power and flow of the two vein SVC+IVC.

N	r (cm)	r(m)	A(m^2)	S(m/s)	ρ (mmHg)	ρ(Pascal)	P(watt)	Q(m^3/s)	P.S+P.I	Q.S+Q.I
1	1.6	0.016	0.000805	0.3	0.49	65.44079	0.015796	0.000241	0.022107	0.000671
2	1.4	0.014	0.000616	0.28	0.51	68.11184	0.011748	0.000172	0.024259	0.00058
3	1.8	0.018	0.001018	0.4	0.39	52.08553	0.021215	0.000407	0.027662	0.00081
4	1.9	0.019	0.001135	0.29	0.35	46.74342	0.01538	0.000329	0.024664	0.000908
5	1.7	0.017	0.000908	0.25	0.31	41.40132	0.009401	0.000227	0.037736	0.000613
6	1.6	0.016	0.000805	0.21	0.22	29.38158	0.004964	0.000169	0.016864	0.000367
7	1.3	0.013	0.000531	0.22	0.52	69.44737	0.008115	0.000117	0.020355	0.000321
8	1.8	0.018	0.001018	0.31	0.51	68.11184	0.021501	0.000316	0.028479	0.000718
9	1.6	0.016	0.000805	0.22	0.39	52.08553	0.009219	0.000177	0.013408	0.000462
10	1.6	0.016	0.000805	0.2	0.19	25.375	0.004083	0.000161	0.014661	0.000359
11	1.8	0.018	0.001018	0.29	0.52	69.44737	0.020508	0.000295	0.048714	0.000647
12	1.8	0.018	0.001018	0.32	0.55	73.45395	0.023935	0.000326	0.053189	0.000782
13	1.4	0.014	0.000616	0.21	0.25	33.38816	0.004319	0.000129	0.009555	0.000241
14	1.4	0.014	0.000616	0.21	0.35	46.74342	0.006047	0.000129	0.021346	0.000384
15	1.6	0.016	0.000805	0.2	0.29	38.73026	0.006232	0.000161	0.016772	0.000415
16	1.5	0.015	0.000707	0.3	0.55	73.45395	0.015583	0.000212	0.028595	0.000526
17	1.6	0.016	0.000805	0.18	0.35	46.74342	0.00677	0.000145	0.015269	0.000399
18	1.5	0.015	0.000707	0.15	0.25	33.38816	0.003542	0.000106	0.010152	0.000248
19	1.6	0.016	0.000805	0.2	0.55	73.45395	0.01182	0.000161	0.02773	0.000501
20	1.9	0.019	0.001135	0.21	0.58	77.46053	0.018456	0.000238	0.057563	0.000771
21	2	0.02	0.001257	0.11	0.48	64.10526	0.008865	0.000138	0.029852	0.000629
22	2	0.02	0.001257	0.31	0.55	73.45395	0.028626	0.00039	0.046944	0.000805
23	1.6	0.016	0.000805	0.21	0.35	46.74342	0.007898	0.000169	0.030614	0.000584
24	1.6	0.016	0.000805	0.2	0.25	33.38816	0.005373	0.000161	0.018547	0.00038
25	1.4	0.014	0.000616	0.25	0.11	14.69079	0.002262	0.000154	0.020154	0.000586
26	1.6	0.016	0.000805	0.2	0.41	54.75658	0.008811	0.000161	0.033995	0.000538
27	1.4	0.014	0.000616	0.11	0.41	54.75658	0.00371	6.78E-05	0.019963	0.000448
28	1.5	0.015	0.000707	0.21	0.35	46.74342	0.006941	0.000149	0.024923	0.000413
29	1.7	0.017	0.000908	0.3	0.55	73.45395	0.020015	0.000272	0.031835	0.000549
30	1.4	0.014	0.000616	0.25	0.45	60.09868	0.009255	0.000154	0.014842	0.000321
31	1.6	0.016	0.000805	0.11	0.45	60.09868	0.005319	8.85E-05	0.015812	0.000403
32	1.4	0.014	0.000616	0.25	0.35	46.74342	0.007198	0.000154	0.019891	0.000788
33	1.4	0.014	0.000616	0.15	0.42	56.09211	0.005183	9.24E-05	0.01685	0.000342
34	1.8	0.018	0.001018	0.2	0.25	33.38816	0.0068	0.000204	0.034103	0.00063
35	1.35	0.0135	0.000573	0.15	0.48	64.10526	0.005508	8.59E-05	0.015503	0.0003
36	1.4	0.014	0.000616	0.37	0.58	77.46053	0.017655	0.000228	0.031708	0.000567
37	1.6	0.016	0.000805	0.25	0.31	41.40132	0.008328	0.000201	0.022648	0.000476
38	1.8	0.018	0.001018	0.2	0.19	25.375	0.005168	0.000204	0.016642	0.000395
39	1.8	0.018	0.001018	0.28	0.34	45.40789	0.012947	0.000285	0.049212	0.000738
40	1.6	0.016	0.000805	0.28	0.25	33.38816	0.007522	0.000225	0.024249	0.000531
41	1.6	0.016	0.000805	0.31	0.31	41.40132	0.010326	0.000249	0.025177	0.000535
42	1.4	0.014	0.000616	0.37	0.58	77.46053	0.017655	0.000228	0.023089	0.000359

Figure (3.1) shows relation between cardiac flow versus power of SVC+ IVC which are to be compared to the output values of the pulmonary artery and with an R value of 0.71 .

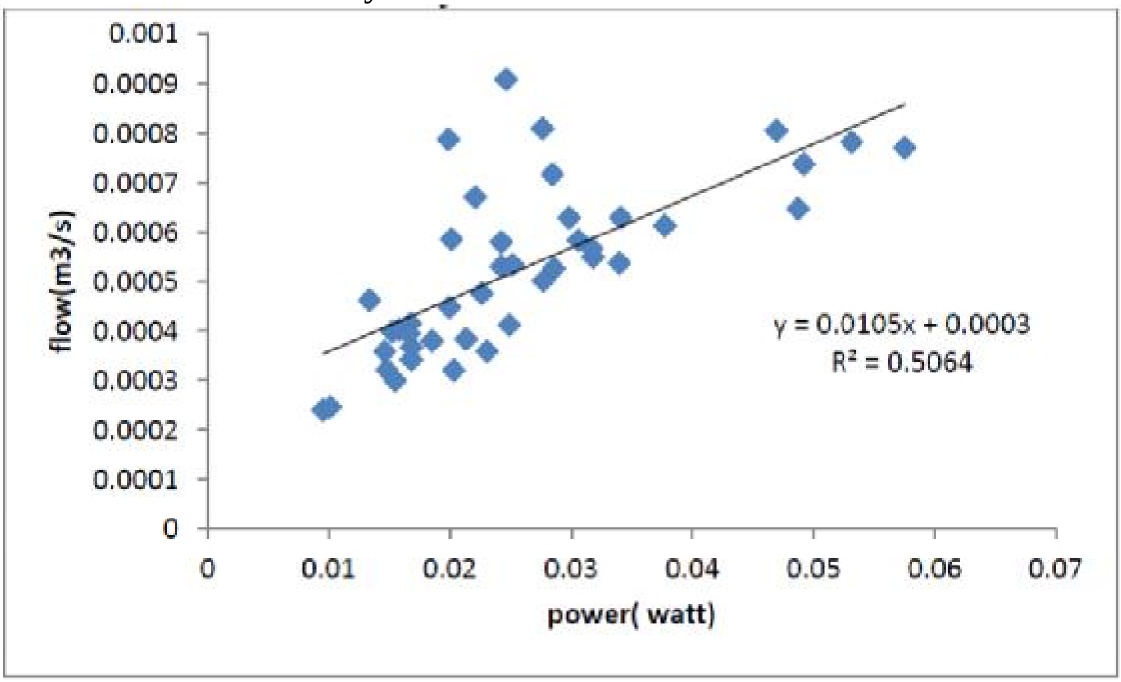


Figure (3.1)

The relation between cardiac flow versus power of SVC+ IVC.

All of the above values work considered as input values of the right side of the heart and all are to be compared to the output values of the pulmonary artery .

Here is table (3.2) shows values of cardiac power and flow of pulmonary artery with values of sum , av , var and t-test see annex A and figure (3.2) shows the relation between cardiac power and flow with R value = 0.89 .

Table (3.2)
The values of cardiac power and flow calculated by there independent values of pulmonary artery.

N	r (cm)	r(m)	$A(m^2)$	S(m/s)	ρ (mmHg)	ρ(Pascal)	P(watt)	$Q(m^3/s)$
1	2.1	0.021	0.001386	0.81	2.94	392.6447	0.440807	0.001123
2	1.9	0.019	0.001135	0.75	2.8	373.9474	0.318203	0.000851
3	2.2	0.022	0.001521	0.7	2.3	307.1711	0.327076	0.001065
4	1.8	0.018	0.001018	0.7	2	267.1053	0.190393	0.000713
5	2	0.02	0.001257	0.62	2.4	320.5263	0.249827	0.000779
6	2.1	0.021	0.001386	0.62	1.8	240.3947	0.206576	0.000859
7	1.9	0.019	0.001135	0.72	2.1	280.4605	0.229106	0.000817
8	2.3	0.023	0.001663	0.75	2.85	380.625	0.474612	0.001247
9	2.2	0.022	0.001521	0.81	3.1	414.0132	0.510116	0.001232
10	2	0.02	0.001257	0.65	2.1	280.4605	0.229176	0.000817
11	1.8	0.018	0.001018	0.8	2.1	280.4605	0.228471	0.000815
12	1.9	0.019	0.001135	0.75	1.9	253.75	0.215923	0.000851
13	2.1	0.021	0.001386	0.79	2.1	280.4605	0.307087	0.001095
14	1.8	0.018	0.001018	0.8	3	400.6579	0.326387	0.000815
15	2	0.02	0.001257	0.85	2.2	293.8158	0.313963	0.001069
16	2.4	0.024	0.00181	1	3.4	454.0789	0.822013	0.00181
17	2	0.02	0.001257	0.8	2.1	280.4605	0.282063	0.001006
18	2.1	0.021	0.001386	0.75	2.2	293.8158	0.305422	0.00104
19	1.6	0.016	0.000805	0.85	2.5	333.8816	0.228337	0.000684
20	1.9	0.019	0.001135	0.78	2.85	380.625	0.33684	0.000885
21	2.1	0.021	0.001386	0.75	2.9	387.3026	0.402601	0.00104
22	2.1	0.021	0.001386	0.75	2.95	393.9803	0.409542	0.00104
23	1.8	0.018	0.001018	0.8	2.65	353.9145	0.288309	0.000815
24	2	0.02	0.001257	0.75	2.35	313.8487	0.295914	0.000943
25	1.8	0.018	0.001018	0.78	2.25	300.4934	0.238671	0.000794
26	1.9	0.019	0.001135	0.9	2	267.1053	0.272745	0.001021
27	2.4	0.024	0.00181	0.75	2.55	340.5592	0.462382	0.001358
28	2	0.02	0.001257	0.65	2.15	287.1382	0.234633	0.000817
29	2	0.02	0.001257	0.65	2.35	313.8487	0.256459	0.000817
30	1.8	0.018	0.001018	0.72	2.45	327.2039	0.239895	0.000733
31	2	0.02	0.001257	0.75	2.58	344.5658	0.324876	0.000943
32	1.6	0.016	0.000805	0.65	2.55	340.5592	0.178103	0.000523
33	1.8	0.018	0.001018	0.78	3.1	414.0132	0.328835	0.000794
34	2	0.02	0.001257	0.72	1.95	260.4276	0.235724	0.000905
35	1.6	0.016	0.000805	0.66	2.2	293.8158	0.156021	0.000531
36	2.2	0.022	0.001521	0.75	2.64	352.5789	0.402242	0.001141
37	1.8	0.018	0.001018	0.71	2.45	327.2039	0.236563	0.000723
38	2	0.02	0.001257	0.66	19	2537.5	0.21054	0.00083
39	1.7	0.017	0.000908	0.8	1.8	240.3947	0.174678	0.000727
40	2.1	0.021	0.001386	0.9	1.9	253.75	0.316528	0.001247
41	1.9	0.019	0.001135	0.8	2.45	327.2039	0.296989	0.000908
42	1.9	0.019	0.001135	0.75	1.64	219.0263	0.186376	0.000851

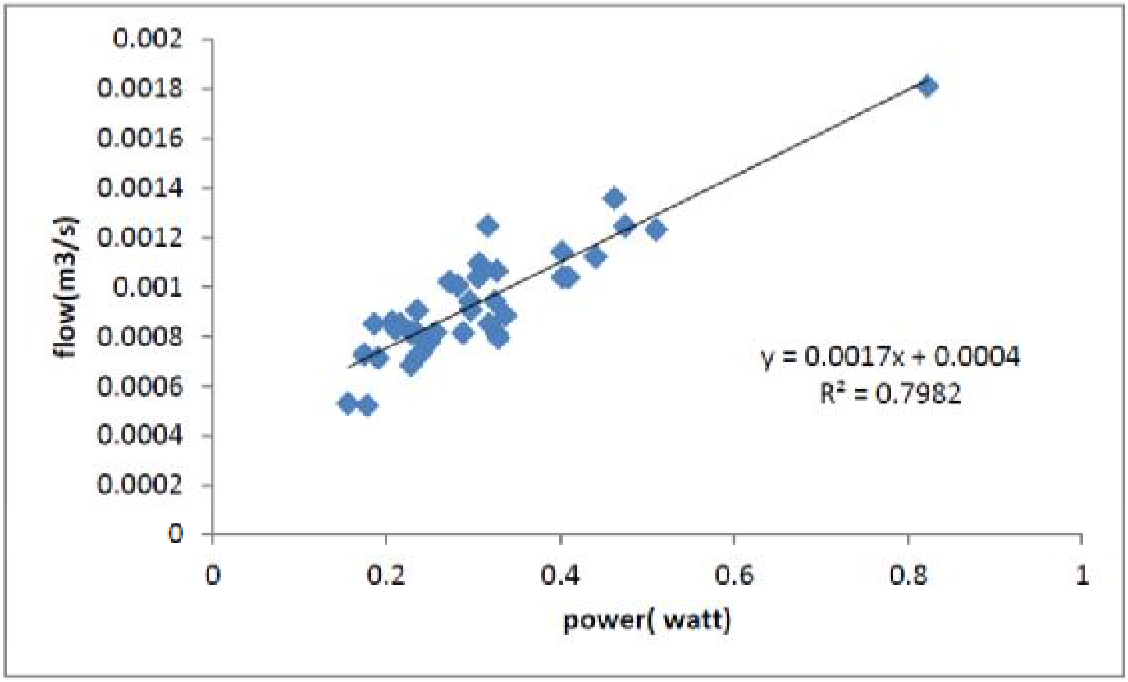


Figure (3.2) The relation between cardiac power versus cardiac flow of the pulmonary artery.

Figures (3.3.a and b) The values to be compared of input and output of flow and power of the right side of the heart with the least R value.

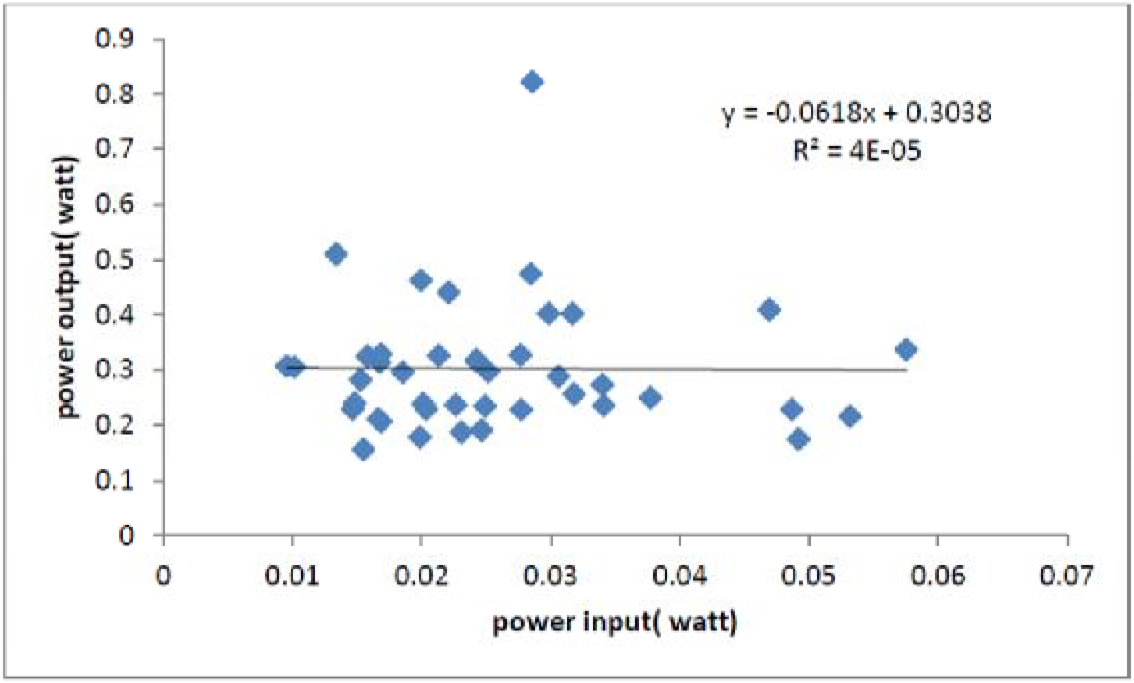


Figure (3.3.a)

shows the relation between cardiac power versus cardiac power of input and output of the right side of the heart.

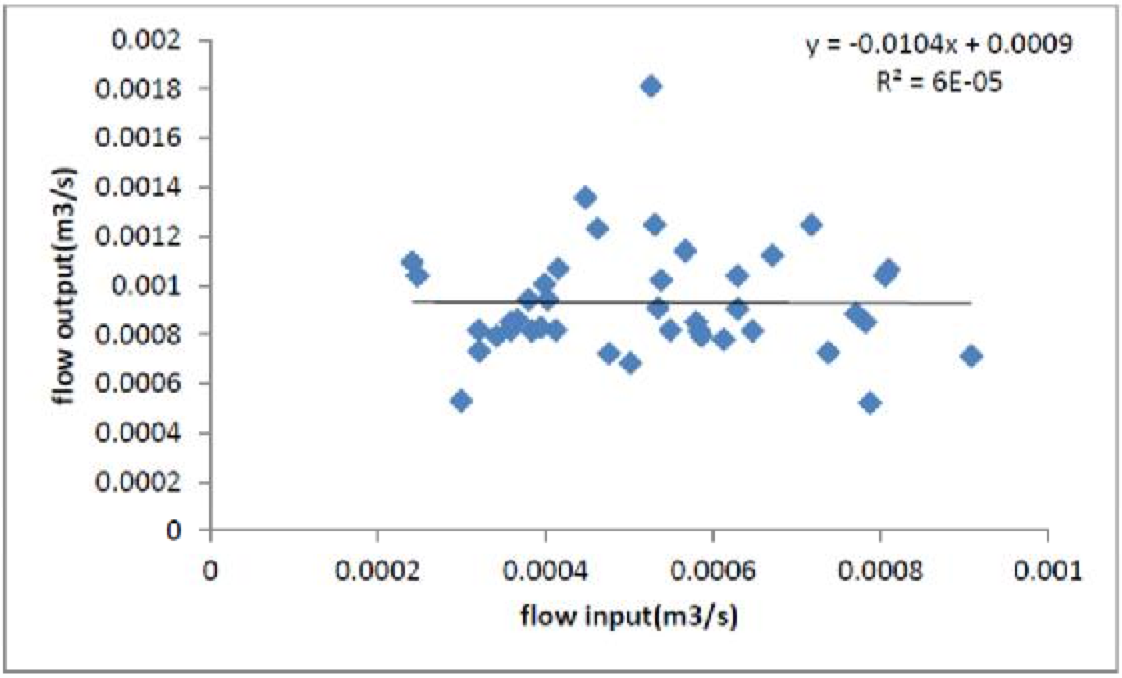


Figure (3.3.b)
shows the relation between cardiac flow versus cardiac flow of input and output of the right side of the heart with less value of R .

3.2 Measurement of power and flow of the left part of the heart

For the second group fundamental parameters are taken to build up a comparison between two dependent variables of flow and power from the independent variables of radius, to calculate area, speed to calculate change in volume and flow, and pressure to calculate power or change in dissipated energy per unit time.

In this section, the second part of present values of the left side of the heart which are being approximated for the difficulty of seeing the four pulmonary veins at the same time, one can be seen easily the other three veins can't be seen, but because three of them were of the same diameter and the fourth is slightly different, measurements were approximated by taking the values of the one seen multiplied by four.

Table (3.4) shows values of pulmonary veins calculated from their independent values with their conversion to S.I units and with values of sum . av . var and t-test see (Appendix A).

Table (3.3)
shows values of pulmonary veins calculated from their independent values with their conversion to S.I units.

N	r (cm)	r(m)	A(m^2)	S(m/s)	ρ (mmHg)	ρ(Pascal)	P(watt)	Q(m^3/s)	4*P(watt)	4*Q((m^3/s
1	**1.1**	**0.011**	**0.00038**	**0.35**	**0.61**	**81.46711**	**0.010843**	**0.000133**	**0.043373**	**0.000532**
2	**1.2**	**0.012**	**0.000453**	**0.38**	**0.59**	**78.79605**	**0.013551**	**0.000172**	**0.054204**	**0.000688**
3	**0.9**	**0.009**	**0.000255**	**0.3**	**0.54**	**72.11842**	**0.005508**	**7.64E-05**	**0.022031**	**0.000305**
4	**0.6**	**0.006**	**0.000113**	**0.25**	**0.61**	**81.46711**	**0.002304**	**2.83E-05**	**0.009217**	**0.000113**
5	**0.9**	**0.009**	**0.000255**	**0.21**	**0.31**	**41.40132**	**0.002213**	**5.35E-05**	**0.008853**	**0.000214**
6	**0.65**	**0.0065**	**0.000133**	**0.21**	**0.31**	**41.40132**	**0.001154**	**2.79E-05**	**0.004618**	**0.000112**
7	**0.9**	**0.009**	**0.000255**	**0.21**	**0.51**	**68.11184**	**0.003641**	**5.35E-05**	**0.014565**	**0.000214**
8	**1.3**	**0.013**	**0.000531**	**0.35**	**0.68**	**90.81579**	**0.016883**	**0.000186**	**0.067531**	**0.000744**
9	**1.2**	**0.012**	**0.000453**	**0.32**	**0.62**	**82.80263**	**0.011992**	**0.000145**	**0.047967**	**0.000579**
10	**0.9**	**0.009**	**0.000255**	**0.22**	**0.29**	**38.73026**	**0.002169**	**5.6E-05**	**0.008676**	**0.000224**
11	**1.2**	**0.012**	**0.000453**	**0.32**	**0.51**	**68.11184**	**0.009864**	**0.000145**	**0.039457**	**0.000579**
12	**0.9**	**0.009**	**0.000255**	**0.21**	**0.4**	**53.42105**	**0.002856**	**5.35E-05**	**0.011424**	**0.000214**
13	**1.2**	**0.012**	**0.000453**	**0.25**	**0.55**	**73.45395**	**0.008311**	**0.000113**	**0.033243**	**0.000453**
14	**1.2**	**0.012**	**0.000453**	**0.3**	**0.62**	**82.80263**	**0.011242**	**0.000136**	**0.044969**	**0.000543**
15	**1.4**	**0.014**	**0.000616**	**0.25**	**0.51**	**68.11184**	**0.010489**	**0.000154**	**0.041957**	**0.000616**
16	**0.9**	**0.009**	**0.000255**	**0.32**	**0.35**	**46.74342**	**0.003808**	**8.15E-05**	**0.015231**	**0.000326**
17	**1.1**	**0.011**	**0.00038**	**0.28**	**0.51**	**68.11184**	**0.007253**	**0.000106**	**0.02901**	**0.000426**
18	**1.3**	**0.013**	**0.000531**	**0.25**	**0.35**	**46.74342**	**0.006207**	**0.000133**	**0.024827**	**0.000531**
19	**1.2**	**0.012**	**0.000453**	**0.11**	**0.55**	**73.45395**	**0.003657**	**4.98E-05**	**0.014627**	**0.000199**
20	**1.5**	**0.015**	**0.000707**	**0.11**	**0.45**	**60.09868**	**0.004675**	**7.78E-05**	**0.018699**	**0.000311**
21	**1.3**	**0.013**	**0.000531**	**0.15**	**0.55**	**73.45395**	**0.005852**	**7.97E-05**	**0.023409**	**0.000319**
22	**1.1**	**0.011**	**0.00038**	**0.3**	**0.54**	**72.11842**	**0.008228**	**0.000114**	**0.032911**	**0.000456**
23	**1.3**	**0.013**	**0.000531**	**0.3**	**0.48**	**64.10526**	**0.010215**	**0.000159**	**0.040859**	**0.000637**
24	**1.1**	**0.011**	**0.00038**	**0.25**	**0.3**	**40.06579**	**0.003809**	**9.51E-05**	**0.015236**	**0.00038**
25	**1.3**	**0.013**	**0.000531**	**0.11**	**0.35**	**46.74342**	**0.002731**	**5.84E-05**	**0.010924**	**0.000234**
26	**1**	**0.01**	**0.000314**	**0.25**	**0.55**	**73.45395**	**0.005771**	**7.86E-05**	**0.023086**	**0.000314**
27	**1.2**	**0.012**	**0.000453**	**0.35**	**0.55**	**73.45395**	**0.011635**	**0.000158**	**0.04654**	**0.000634**
28	**1.4**	**0.014**	**0.000616**	**0.35**	**0.62**	**82.80263**	**0.017852**	**0.000216**	**0.071409**	**0.000862**
29	**0.9**	**0.009**	**0.000255**	**0.3**	**0.48**	**64.10526**	**0.004896**	**7.64E-05**	**0.019583**	**0.000305**
30	**1.3**	**0.013**	**0.000531**	**0.25**	**0.45**	**60.09868**	**0.00798**	**0.000133**	**0.031921**	**0.000531**
31	**1.4**	**0.014**	**0.000616**	**0.25**	**0.35**	**46.74342**	**0.007198**	**0.000154**	**0.028794**	**0.000616**
32	**1.2**	**0.012**	**0.000453**	**0.35**	**0.45**	**60.09868**	**0.00952**	**0.000158**	**0.038079**	**0.000634**
33	**0.95**	**0.0095**	**0.000284**	**0.25**	**0.55**	**73.45395**	**0.005209**	**7.09E-05**	**0.020835**	**0.000284**
34	**1**	**0.01**	**0.000314**	**0.25**	**0.55**	**73.45395**	**0.005771**	**7.86E-05**	**0.023086**	**0.000314**
35	**1.2**	**0.012**	**0.000453**	**0.35**	**0.45**	**60.09868**	**0.00952**	**0.000158**	**0.038079**	**0.000634**
36	**0.5**	**0.005**	**7.86E-05**	**0.35**	**0.55**	**73.45395**	**0.00202**	**2.75E-05**	**0.00808**	**0.00011**
37	**1.4**	**0.014**	**0.000616**	**0.3**	**0.44**	**58.76316**	**0.010859**	**0.000185**	**0.043438**	**0.000739**
38	**0.8**	**0.008**	**0.000201**	**0.24**	**0.28**	**37.39474**	**0.001805**	**4.83E-05**	**0.007221**	**0.000193**
39	**1**	**0.01**	**0.000314**	**0.32**	**0.48**	**64.10526**	**0.006447**	**0.000101**	**0.025789**	**0.000402**
40	**1.2**	**0.012**	**0.000453**	**0.28**	**0.39**	**52.08553**	**0.0066**	**0.000127**	**0.026401**	**0.000507**
41	**1.1**	**0.011**	**0.00038**	**0.31**	**0.39**	**52.08553**	**0.00614**	**0.000118**	**0.024561**	**0.000472**
42	**0.9**	**0.009**	**0.000255**	**0.35**	**0.55**	**73.45395**	**0.006545**	**8.91E-05**	**0.026179**	**0.000356**

Figure (3.4) shows relation between cardiac flow versus power of pulmonary veins with value of R =0.93 .

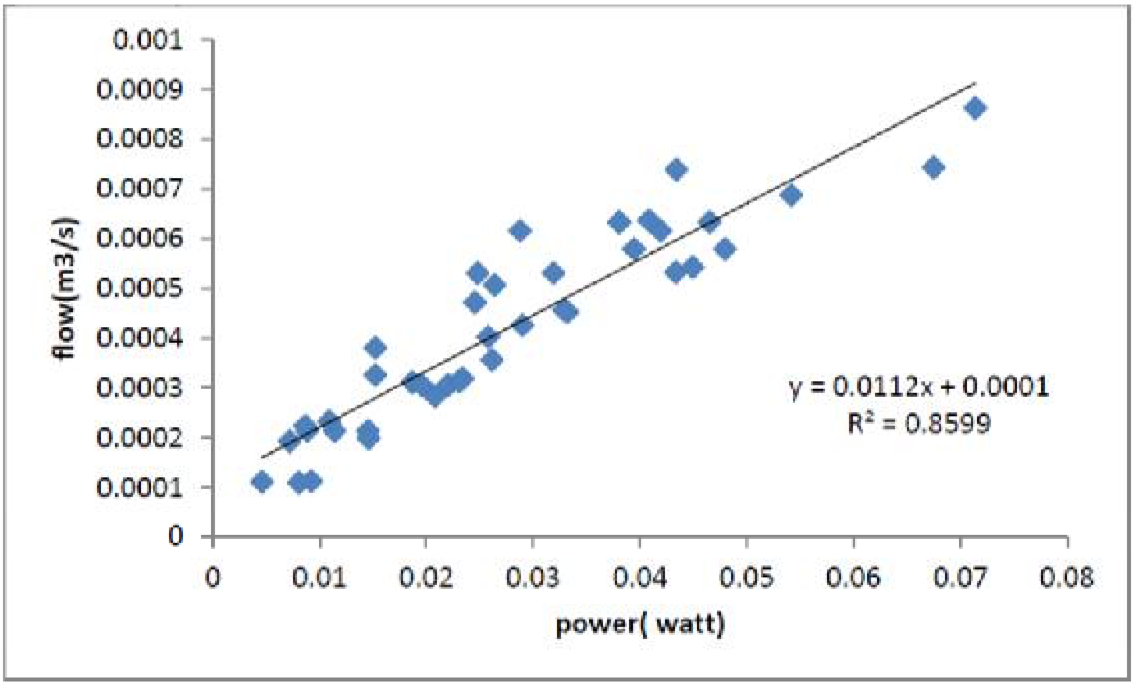


Figure (3.4)

The relation between cardiac flow versus power of pulmonary veins

Values of pulmonary veins are considered to be input of the left side and the coming values of the aorta are considered to be the output of the left side(see values of table 3.5 and figure 3.5) with values of sum , av , var and t-test see annex A .

Table (3.4)
shows values of cardiac power and flow calculated by their independent values.

N	r (cm)	r(m)	$A(m^2)$	S(m/s)	ρ (mmHg)	ρ(Pascal)	P(watt)	$Q(m^3/s)$
1	2.2	0.022	0.001521	0.84	3.21	428.7039	0.547781	0.001278
2	1.8	0.018	0.001018	0.81	3	400.6579	0.330467	0.000825
3	2.1	0.021	0.001386	0.8	3	400.6579	0.444249	0.001109
4	1.9	0.019	0.001135	0.78	2.1	280.4605	0.248198	0.000885
5	2	0.02	0.001257	0.68	2.51	335.2171	0.286563	0.000855
6	2.2	0.022	0.001521	0.73	2.62	349.9079	0.38855	0.00111
7	2.2	0.022	0.001521	0.81	2.7	360.5921	0.444295	0.001232
8	2.2	0.022	0.001521	0.8	2.95	393.9803	0.47944	0.001217
9	2.4	0.024	0.00181	0.82	3.2	427.3684	0.6344	0.001484
10	2	0.02	0.001257	0.7	2.51	335.2171	0.294991	0.00088
11	1.8	0.018	0.001018	1	3.2	427.3684	0.435183	0.001018
12	1.9	0.019	0.001135	0.9	3.1	414.0132	0.422755	0.001021
13	2.2	0.022	0.001521	0.85	3.1	414.0132	0.535307	0.001293
14	1.9	0.019	0.001135	0.85	3.35	447.4013	0.431467	0.000964
15	2.2	0.022	0.001521	0.95	3.1	414.0132	0.598285	0.001445
16	2.5	0.025	0.001964	1.1	4.5	600.9868	1.298561	0.002161
17	2.1	0.021	0.001386	0.95	2.9	387.3026	0.509961	0.001317
18	2.2	0.022	0.001521	1	3.4	454.0789	0.690719	0.001521
19	1.9	0.019	0.001135	0.9	2.95	393.9803	0.402299	0.001021
20	2.1	0.021	0.001386	0.81	3.1	414.0132	0.464796	0.001123
21	2.2	0.022	0.001521	0.95	3.25	434.0461	0.627234	0.001445
22	2.2	0.022	0.001521	0.9	3	400.6579	0.548512	0.001369
23	1.9	0.019	0.001135	0.95	3.95	527.5329	0.568598	0.001078
24	2	0.02	0.001257	0.8	2.55	340.5592	0.342505	0.001006
25	1.9	0.019	0.001135	0.9	3.1	414.0132	0.422755	0.001021
26	1.9	0.019	0.001135	1	3.8	507.5	0.575795	0.001135
27	2.5	0.025	0.001964	0.85	2.9	387.3026	0.646657	0.00167
28	2.1	0.021	0.001386	0.75	3	400.6579	0.416484	0.00104
29	2	0.02	0.001257	0.82	3.2	427.3684	0.440556	0.001031
30	1.9	0.019	0.001135	0.8	3	400.6579	0.36366	0.000908
31	2.1	0.021	0.001386	0.95	2.85	380.625	0.501169	0.001317
32	1.8	0.018	0.001018	0.75	2.95	393.9803	0.300888	0.000764
33	2	0.02	0.001257	0.85	3.25	434.0461	0.463809	0.001069
34	2	0.02	0.001257	0.95	3.45	460.7566	0.550275	0.001194
35	1.8	0.018	0.001018	0.9	3.15	420.6908	0.385545	0.000916
36	2.2	0.022	0.001521	0.84	3.19	426.0329	0.544368	0.001278
37	1.8	0.018	0.001018	1	4.92	657.0789	0.669094	0.001018
38	2	0.02	0.001257	0.71	2.57	343.2303	0.306358	0.000893
39	1.8	0.018	0.001018	1	3.7	494.1447	0.503181	0.001018
40	2.2	0.022	0.001521	1	2.85	380.625	0.578985	0.001521
41	2	0.02	0.001257	1.1	2.95	393.9803	0.544818	0.001383
42	1.9	0.019	0.001135	0.8	2.7	360.5921	0.327294	0.000908

Figure (3.5) shows relation between cardiac flow versus power of aorta with R value 0.89.

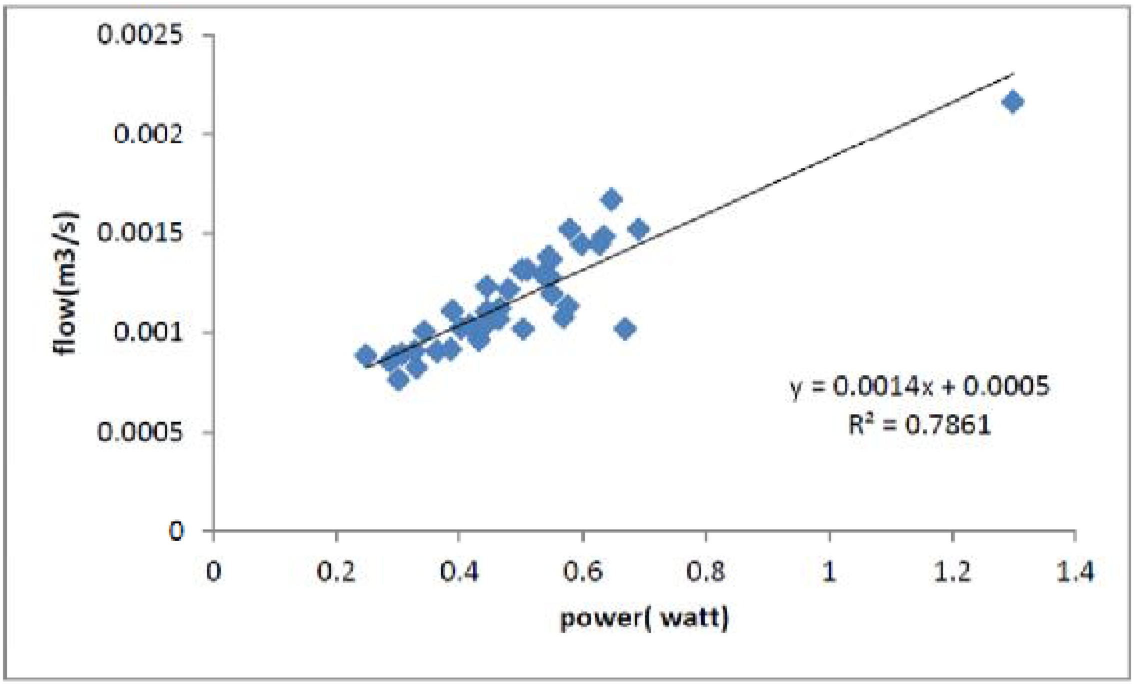


Figure (3.5)

The relation between cardiac flow versus power of aorta.

All of the above values in the second part are values of the left side input and output of the cardiac power and flow .

To compare values of cardiac power of input and output and cardiac flow of input and output its seen in figure (3.6.a and 3.6.b).

Figure (3.6.a) shows the relation between cardiac power versus cardiac power of input and output of the left side of the heart with least value of R.

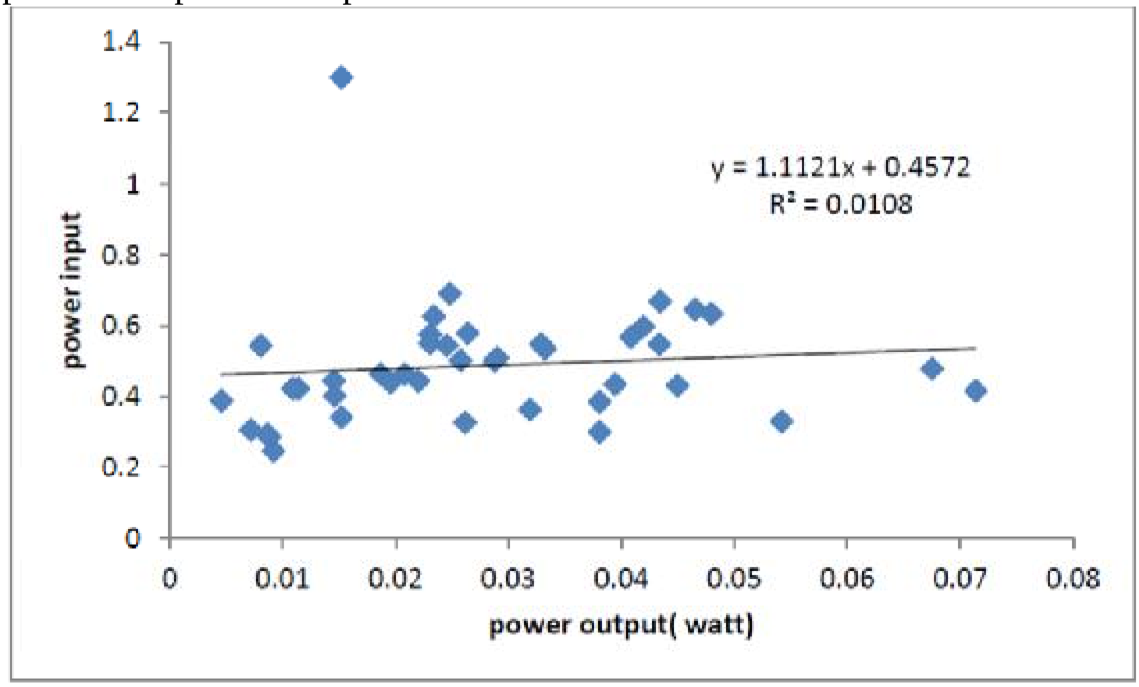


Figure (3.6.a)
The relation between cardiac power versus cardiac power of input and output of the left side of the heart

Figure (3.6.b) shows the relation between cardiac flow versus cardiac flow of input and output of the left side of the heart with least value of R.

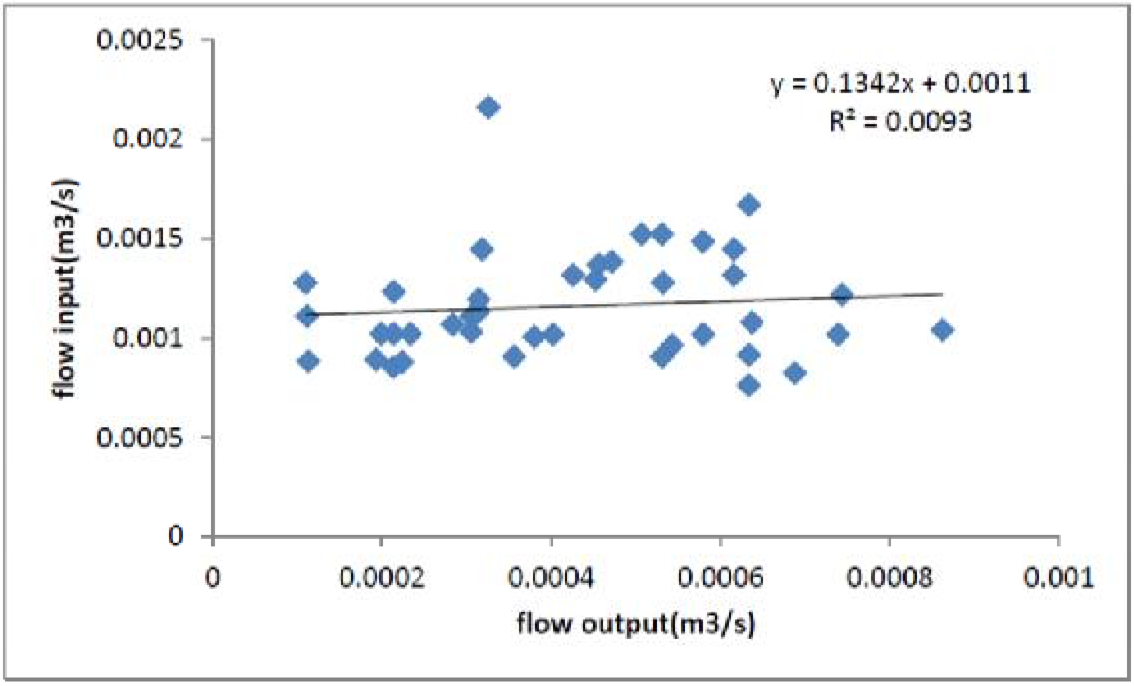


Figure (3.6.b)
The relation between cardiac flow versus cardiac flow of input and output of the left side of the heart.

All of the above are values in the second group(values of the input and the output of the left side of the heart).

3.3 Measurement of power and flow of the heart as a whole

For the third group fundamental parameters are taken to build up a comparison between two dependent variables of flow and power from the independent variables of radius, to calculate area, speed to calculate change in volume and flow, and pressure to calculate power or change in dissipated energy per unit time.

From table (3.1) with table (3.5) and figure (3.5) to compare the total power and total flow of the whole heart input and output.

Figure (3.7.a) shows the relation between cardiac power versus cardiac power of input and output of the whole heart with least value of R.

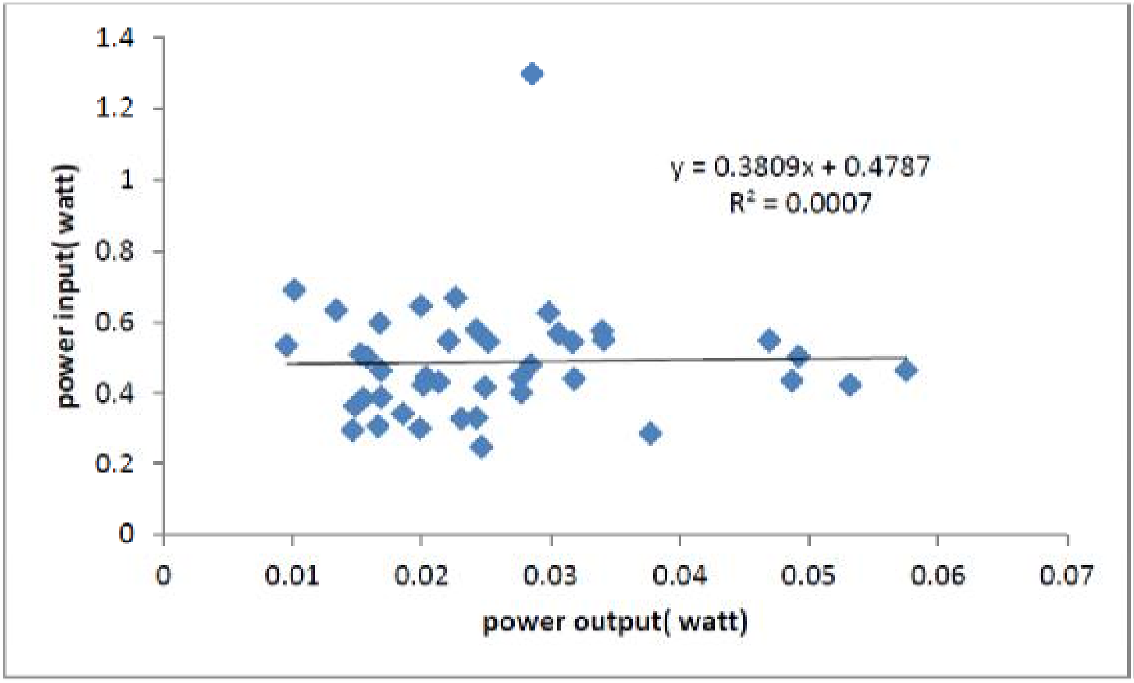


Figure (3.7.a)

The relation between cardiac power versus cardiac power of input and output of the whole heart.

Figure (3.7.b) shows the relation between cardiac flow versus cardiac flow of input and output of the whole heart with least value of R.

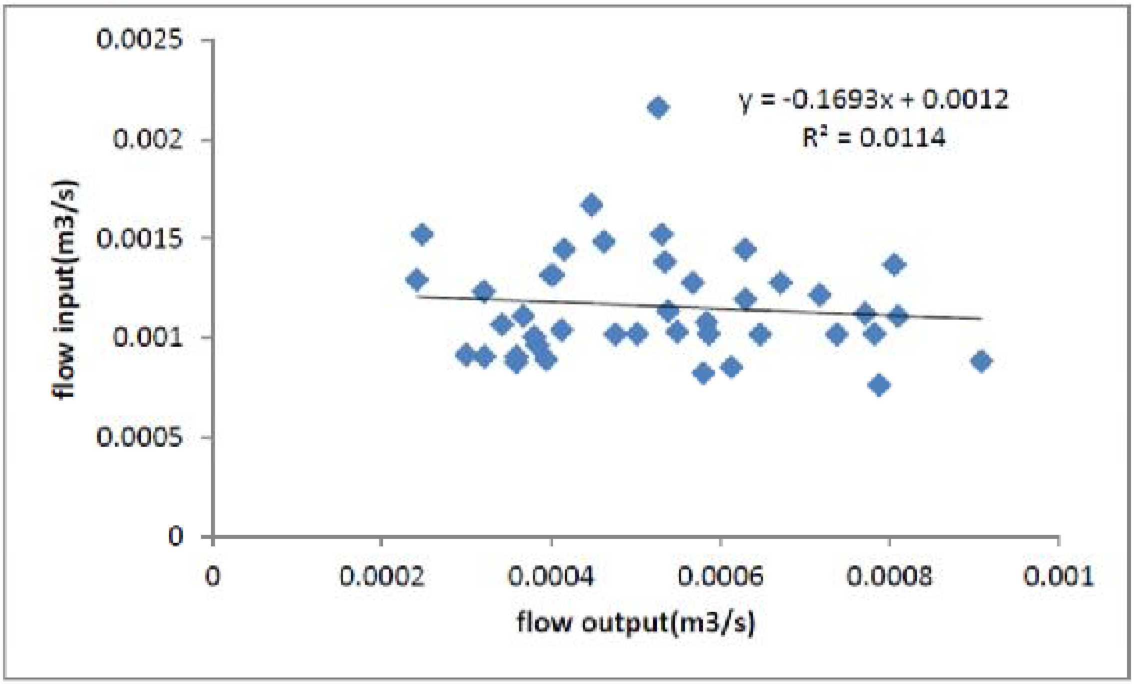


Figure (3.7.b)

The relation between cardiac flow versus cardiac flow of input and output of the whole heart.

3.4 A comparison of cardiac power and flow with their efficiencies

Efficiency is an important value to be calculated because it's a good indicator for the characteristics of any machine to be studied, for physicist heart is considered as a mechanical pump of fluid .

3.4.a mathematical model to compare power and flow of the right side with efficiencies

After the calculation of the efficiency for the right side of the heart, the data were illustrated in annex B and here are the figures of input power and flow versus the efficiencies of power and flow of right side of the heart in figures (3.8.a and b) with R value of 0.77 for the power and 0.82 for flow.

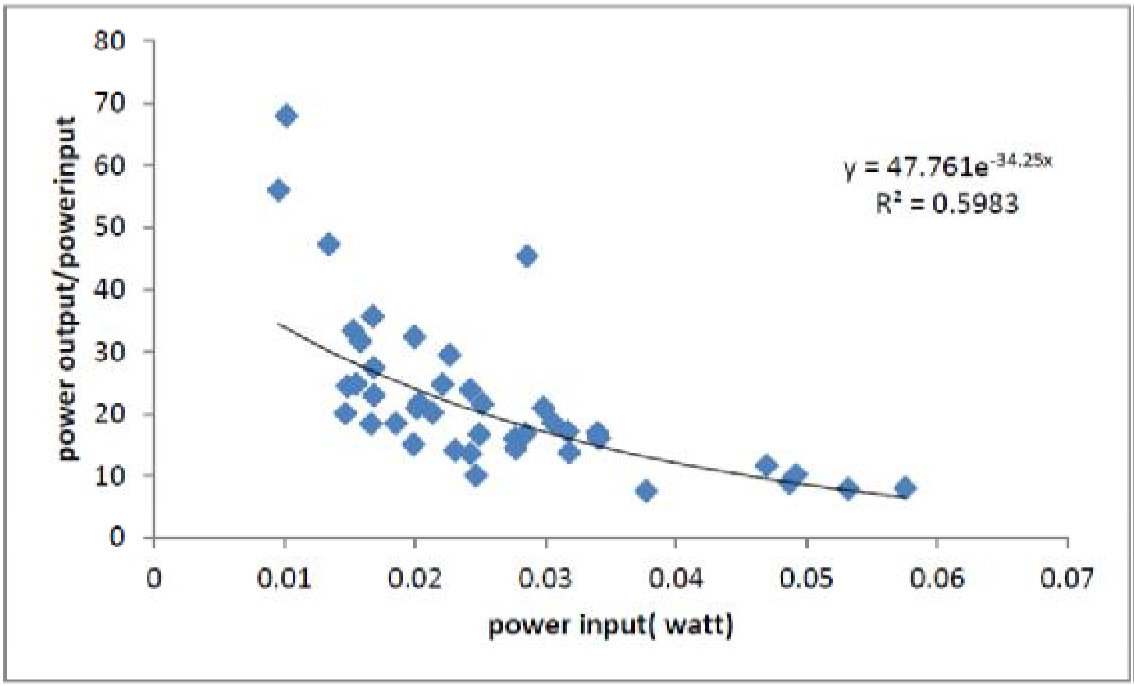


Figure (3.8.a)

The relation between input power versus efficiencies of the right side

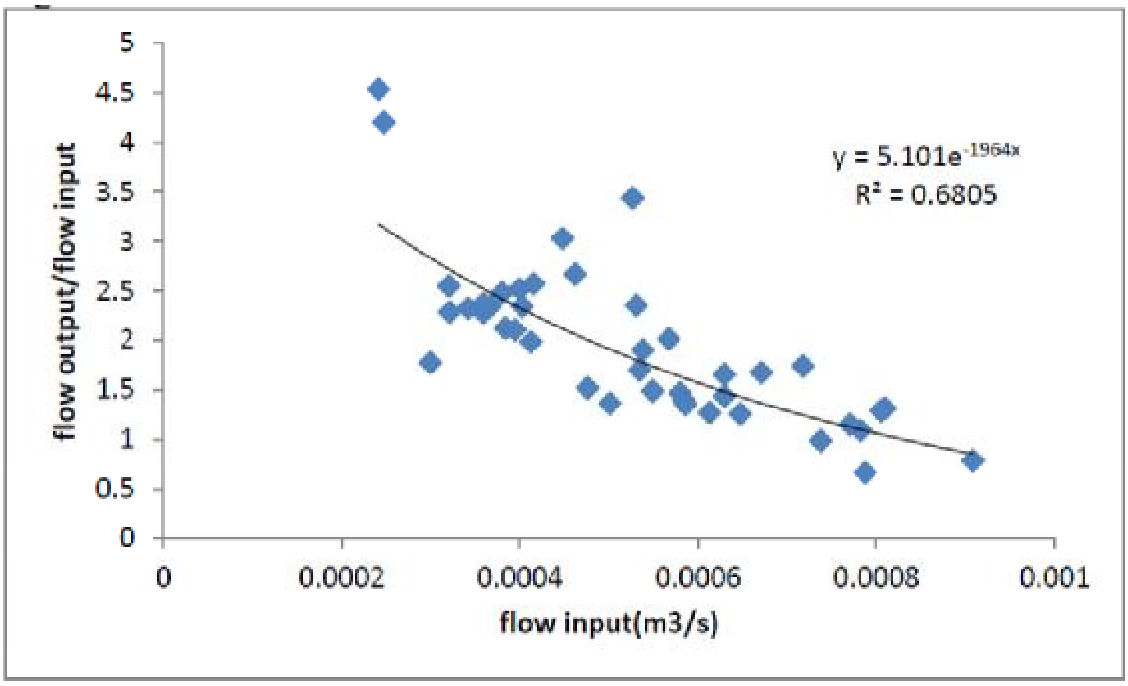


Figure (3.8.b)
The relation between input flow versus efficiencies of the right side.

3.4.b mathematical model to compare power and flow of the left side with efficiencies

After the calculation of the efficiency for the left side of the heart , the data were illustrated in annex B and here are the figures of input power and flow versus the efficiencies of power and flow of left side of the heart in figures (3.9.a and b) with R value of 0.42 for the power and 0.36 for flow.

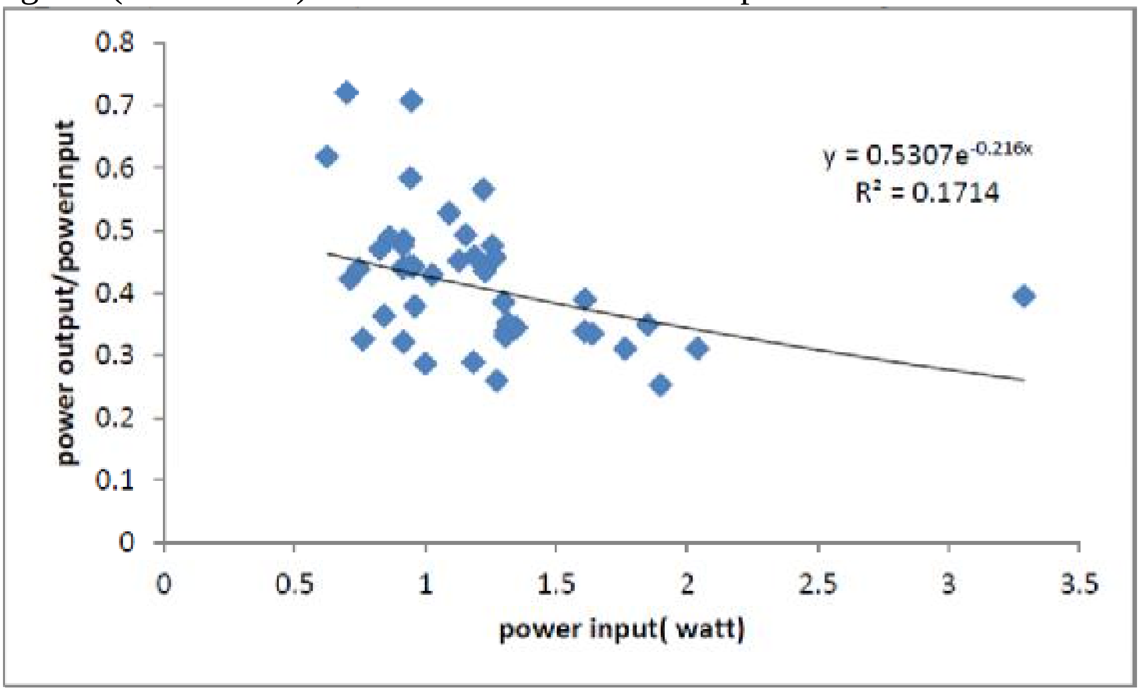


Figure (3.9.a)
The relation between input power versus efficiencies of the left side.

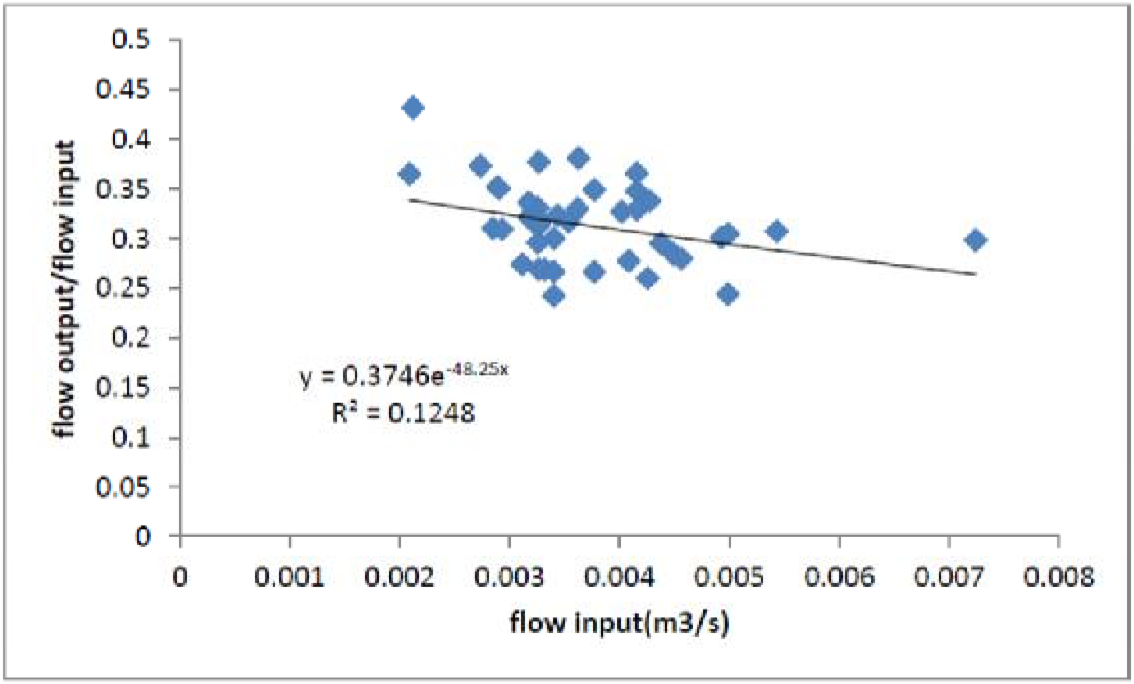


Figure (3.9.b)

The relation between input flow versus efficiencies of the left side

3.4.c mathematical model to compare power and flow of the whole heart with efficiencies

After the calculation of the efficiency for the heart as whole , the data were illustrated in annex B and here are the figures of input power and flow versus the efficiencies of power and flow of the heart in figures (3.10.a and b) with R value of 0.77 for the power and 0.85 for flow.

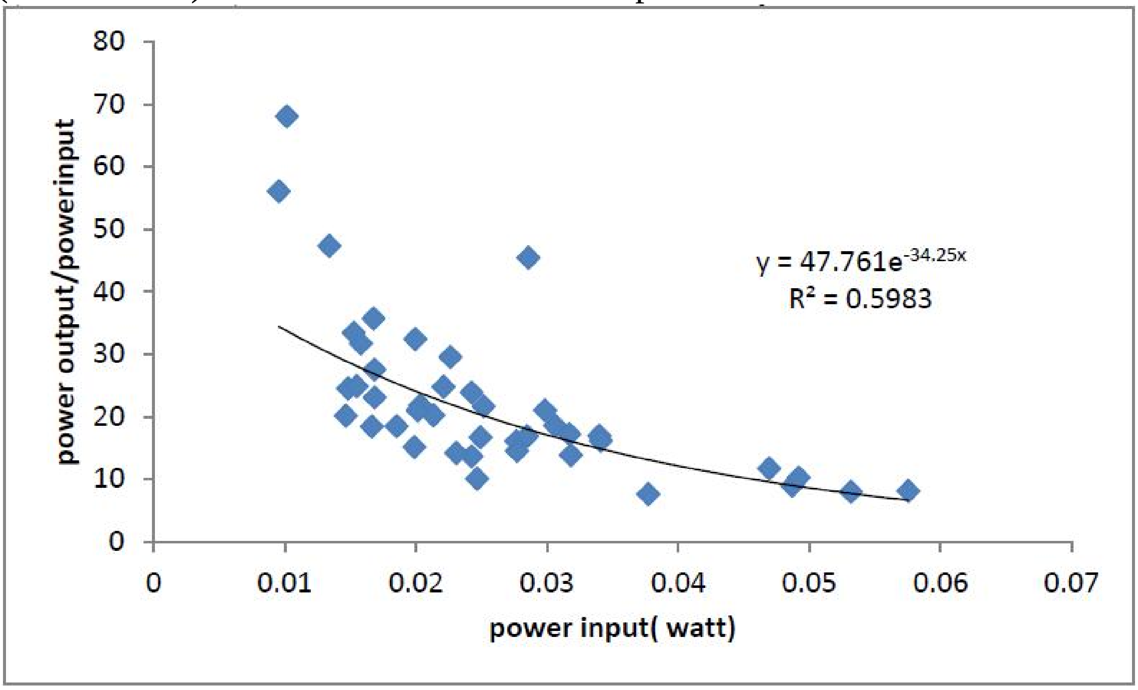


Figure (3.10.a)

The relation between input power versus efficiencies of the heart as a whole.

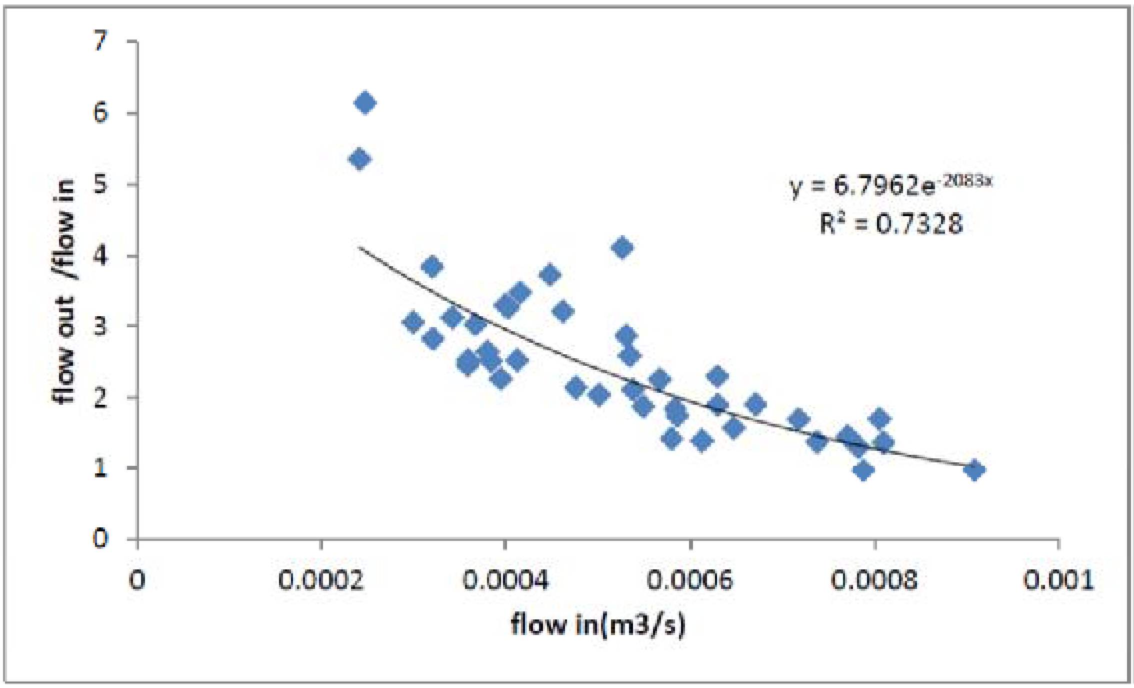


Figure (3.10.b)
The relation between input flow versus efficiencies of the heart as a whole

3.5 A comparison of abnormal cases with normal.

Five cases of abnormal state was taken for a comparison (see Appendix C).

For abnormals, the same variables were studied after measuring radii, speed and pressure to calculate flow and power and to be compared with normal.

Table (3.5)
the relations of abnormals.

N	r (cm)	r(m)	$A(m^2)$	S(m/s)	ρ (mmHg)	ρ(Pascal)	P(watt)	$Q(m^3/s)$
				Superior vena cava				
1	2.1	0.021	0.001386	0.31	0.11	14.69079	0.006312	0.00043
2	2.4	0.024	0.00181	0.32	0.12	16.02632	0.009284	0.000579
3	2.2	0.022	0.001521	0.35	0.55	73.45395	0.039107	0.000532
4	2.5	0.025	0.001964	0.25	0.32	42.73684	0.020987	0.000491
5	2.4	0.024	0.00181	0.35	0.15	20.03289	0.012693	0.000634
				Inferior vena cava				
N	r (cm)	r(m)	$A(m^2)$	S(m/s)	ρ (mmHg)	ρ(Pascal)	P(watt)	$Q(m^3/s)$
1	1.6	0.016	0.000805	0.3	0.49	65.44079	0.015796	0.000241
2	1.9	0.019	0.001135	0.29	0.35	46.74342	0.01538	0.000329
3	1.9	0.019	0.001135	0.21	0.58	77.46053	0.018456	0.000238
4	2	0.02	0.001257	0.11	0.48	64.10526	0.008865	0.000138
5	1.4	0.014	0.000616	0.25	0.35	46.74342	0.007198	0.000154
				Pulmonary artery				
N	r (cm)	r(m)	$A(m^2)$	S(m/s)	ρ (mmHg)	ρ(Pascal)	P(watt)	$Q(m^3/s)$
1	2.1	0.021	0.001386	0.81	2.94	392.6447	0.440807	0.001123
2	1.8	0.018	0.001018	0.7	2	267.1053	0.190393	0.000713
3	1.9	0.019	0.001135	0.78	2.85	380.625	0.33684	0.000885
4	2.1	0.021	0.001386	0.75	2.9	387.3026	0.402601	0.00104
5	1.6	0.016	0.000805	0.65	2.55	340.5592	0.178103	0.000523
				Pulmonary aorta				
N	r (cm)	r(m)	$A(m^2)$	S(m/s)	ρ (mmHg)	ρ(Pascal)	P(watt)	$Q(m^3/s)$
1	2.2	0.022	0.001521	0.84	3.21	428.7039	0.547781	0.001278
2	1.9	0.019	0.001135	0.78	2.1	280.4605	0.248198	0.000885
3	2.1	0.021	0.001386	0.81	3.1	414.0132	0.464796	0.001123
4	2.2	0.022	0.001521	0.95	3.25	434.0461	0.627234	0.001445
5	1.8	0.018	0.001018	0.75	2.95	393.9803	0.300888	0.000764

1. Figure (3.11) shows flow versus power of abnormal subjects of SVC+IVC with their least value of R , this figure differ from first step of normal subject figure(3.1) which gave a linear variation between flow and power of normal, which is considered the input values for normal and abnormal.

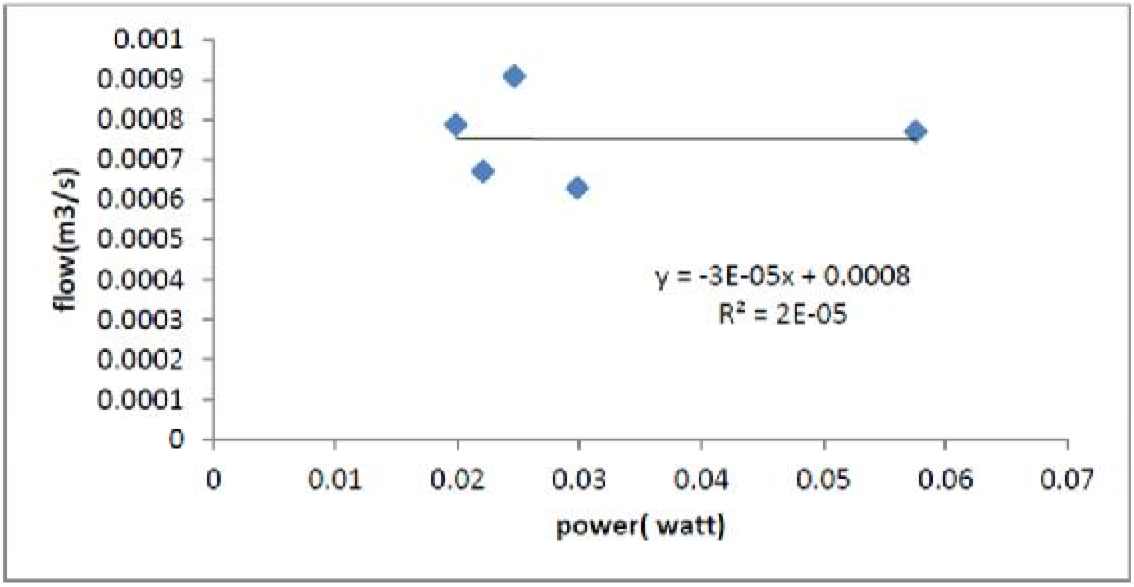


Figure (3.11)

The flow versus power of SVC+IVC for abnormal.

2. Figure (3.12) shows flow versus power of pulmonary artery for abnormal, to be compared with normal, the line of normal gave a similar linear function which also about the same slope but the R value for abnormals is higher than and very near to 1 while for normal R value was less than the abnormal subject.

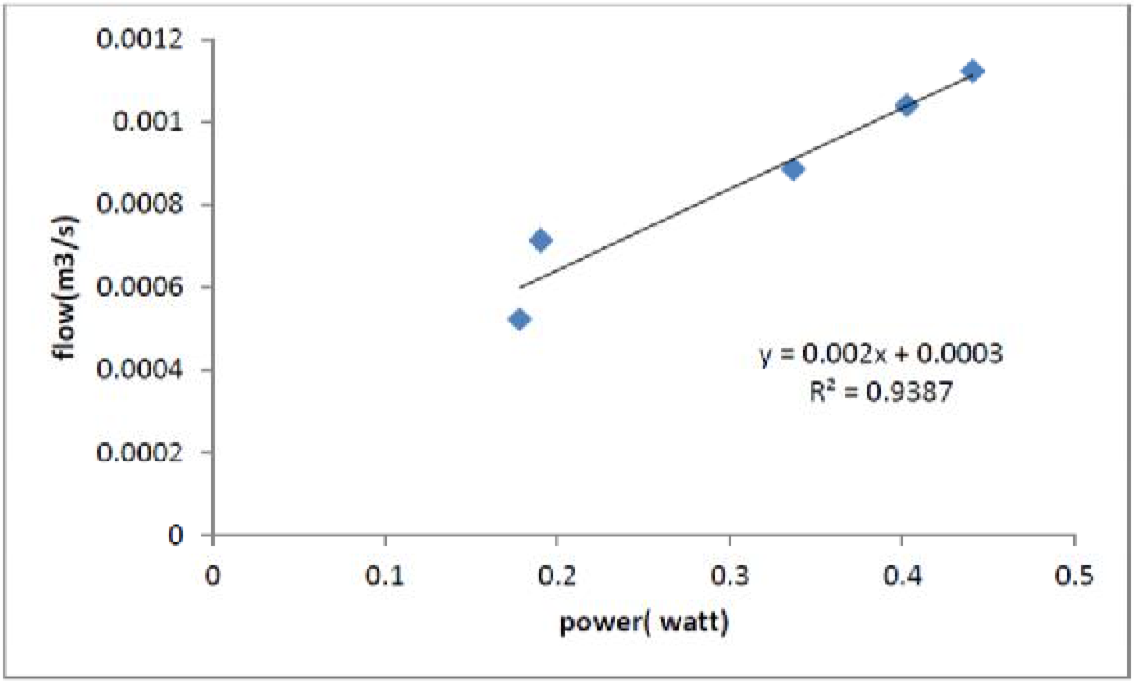


Figure (3.12)

The flow versus power of pulmonary artery for abnormal.

3. Figure (3.13) shows values of SVC+IVC versus pulmonary artery of input versus output power, it gave a linear value between input and output power with a slope value higher than the slope of power of normal and with an R value 0.22.

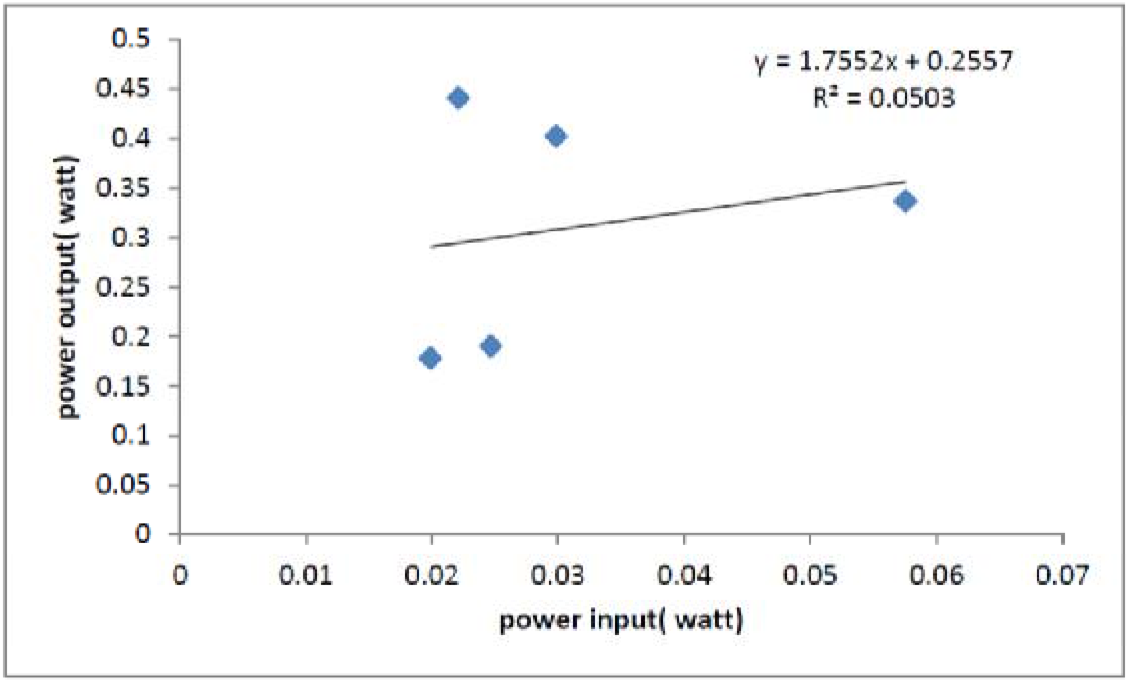


Figure (3.13)

The values of SVC+IVC versus pulmonary artery of input versus output power for abnormal.

4. Figure(3.14) shows SVC+IVC versus pulmonary artery input and output values of flow for abnormal which gave an inverse linear line of inverse value of slope, while for normal line was nearly constant with least value of R=0.73 and slope.

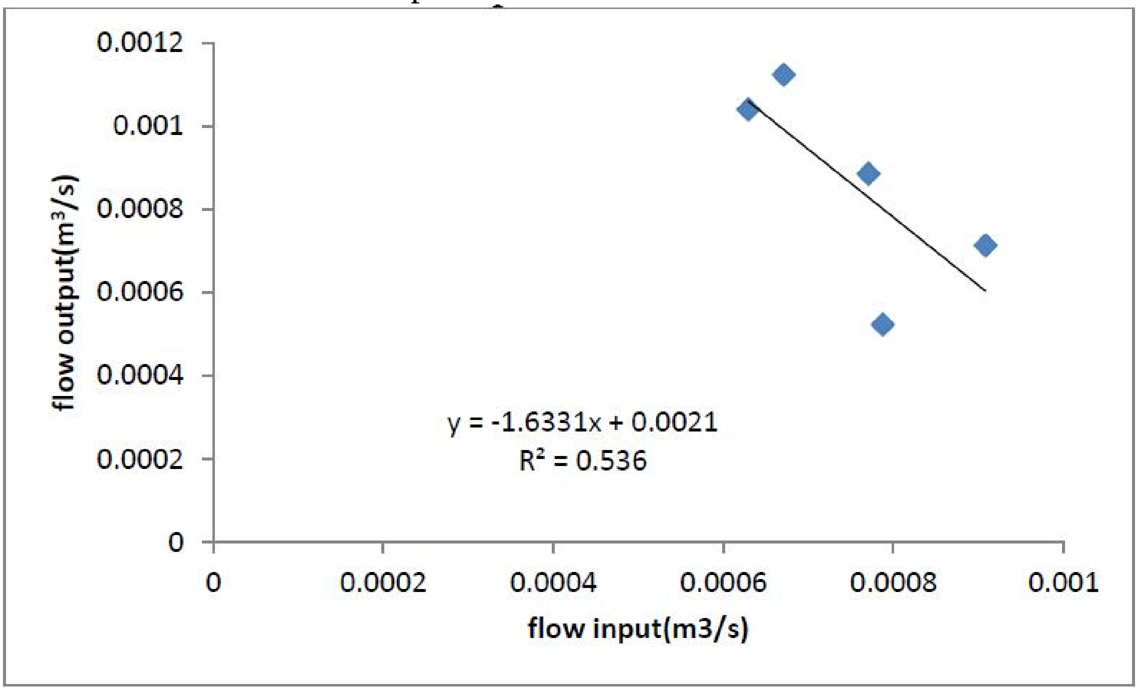


Figure (3.14)

The values of SVC+IVC versus pulmonary artery of input versus output flow for abnormal

5. Figure (3.15) shows values of flow versus power of aorta for abnormal with its linear line and high value of R=0.96 which is more than the value of R=0.89 for normal.

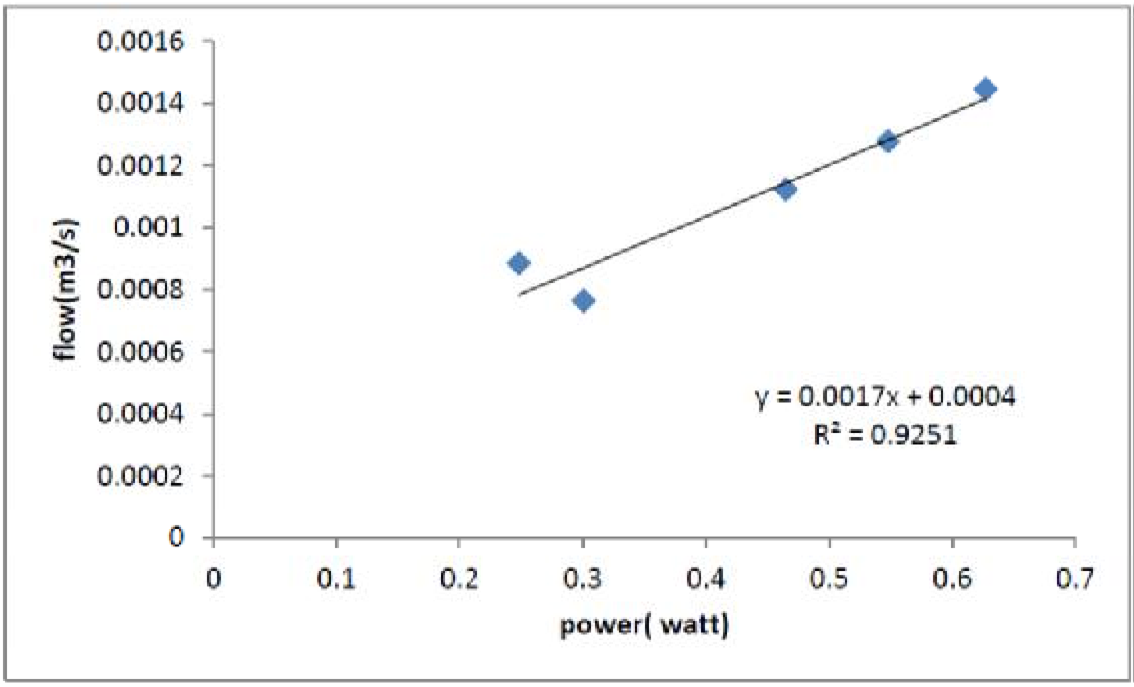
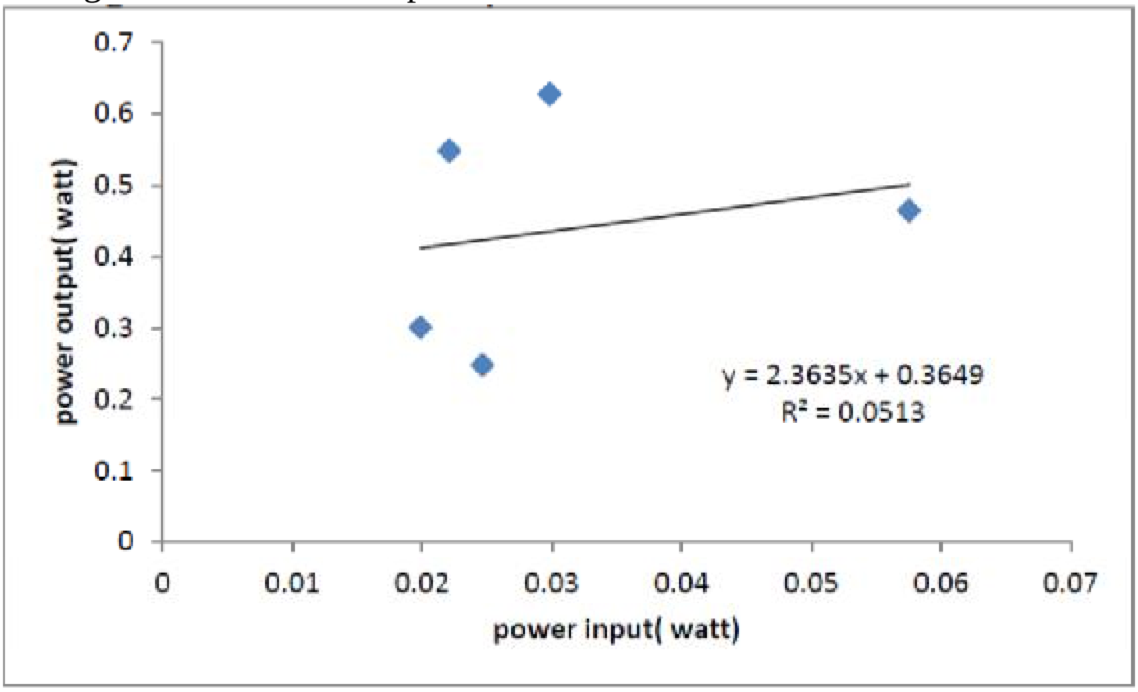


Figure (3.15)

The flow versus power of aorta for abnormal.

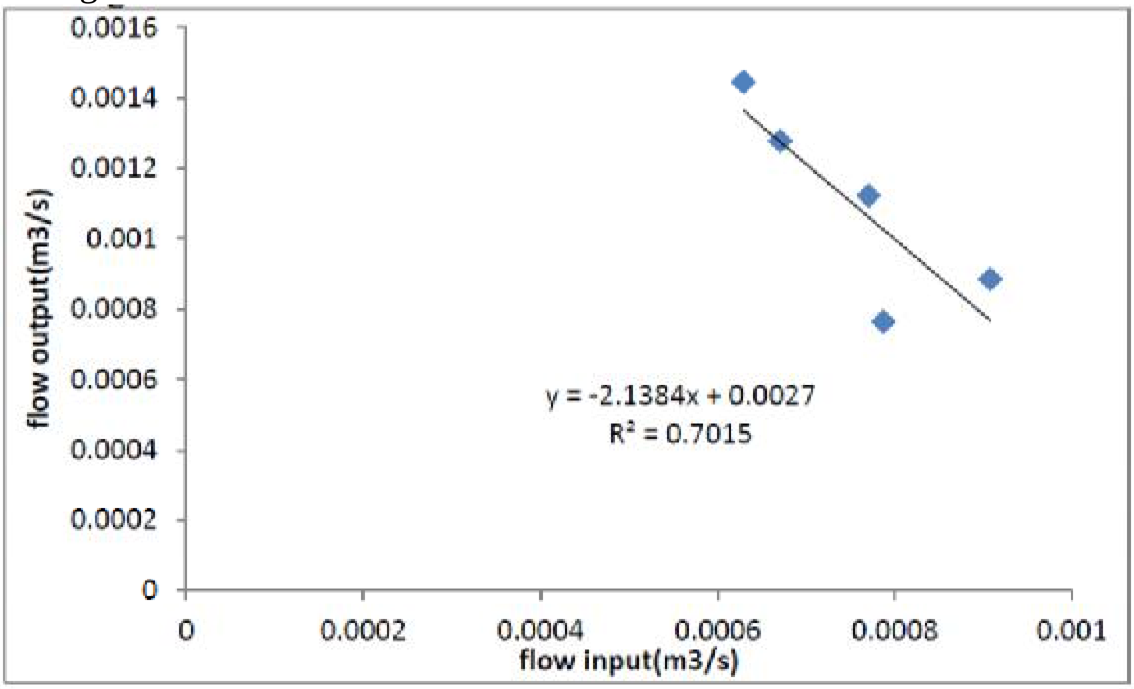
6. Figure 3.16 shows values of power versus power for aorta of abnormal subjects with slight linearity but it has value of slope and R values 0.22 higher than value of slope and R values for normal.



Figure(3.16)

The values of power versus power for aorta of abnormal.

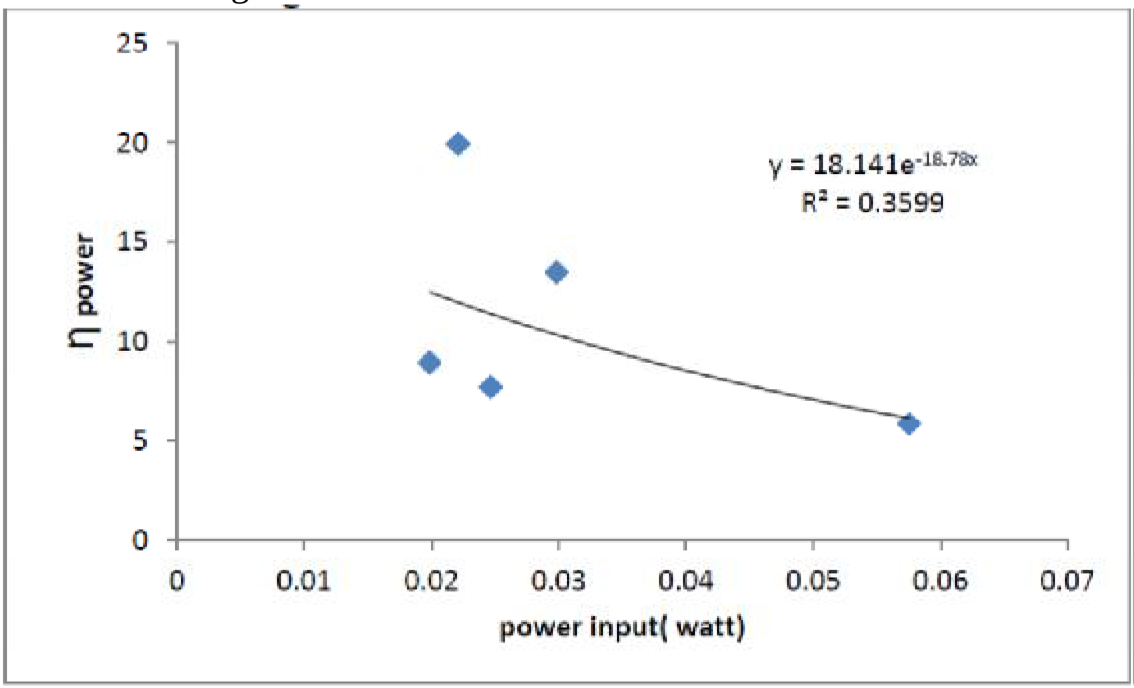
7. Figure(3.17) shows values flow versus flow of aorta for abnormal which gave a high value of slope in spite of its inverse proportionality and with high value of R more that of normal.



Figure(3.17)

The values of power versus flow for aorta of abnormal.

8. Figure(3.18) shows values of efficiency of power versus input power of right side with it exponential trend of abnormal. First value of efficiency began with 18.14 while for normal began with 30.56 but R value for normal is higher than that of abnormal.



Figure(3.18)

The values of efficiency of power versus input power of right side of heart.

9. Figure (3.19) shows values of efficiency of flow versus input flow of right side with its higher value of start for abnormal but R value is nearly the same for normal and abnormal.

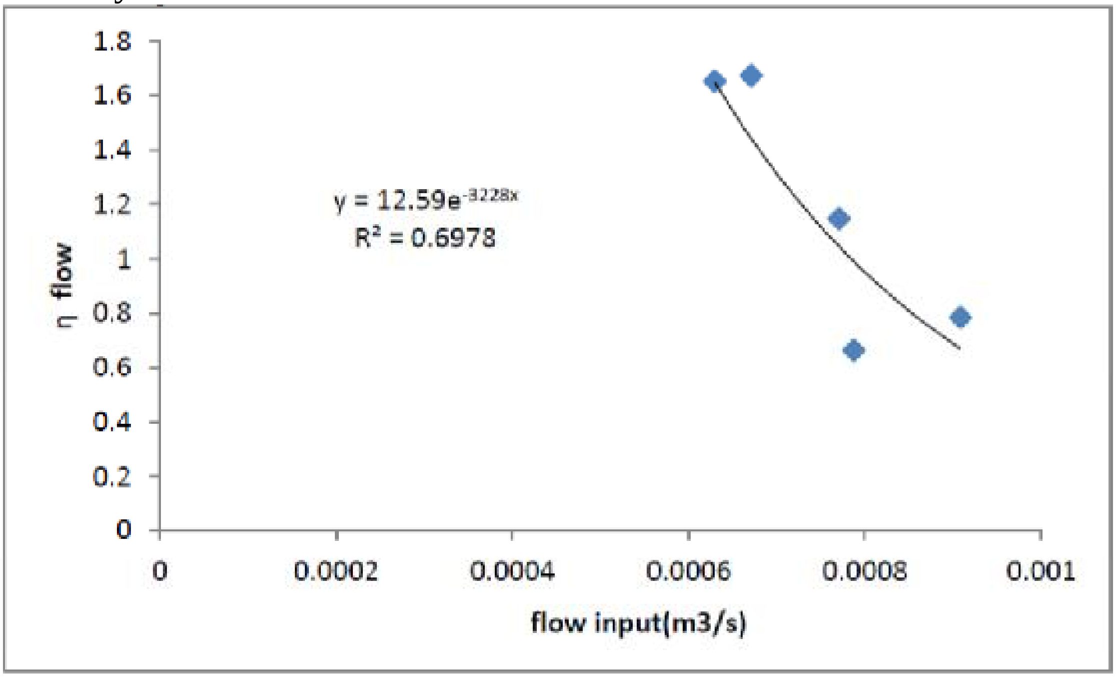
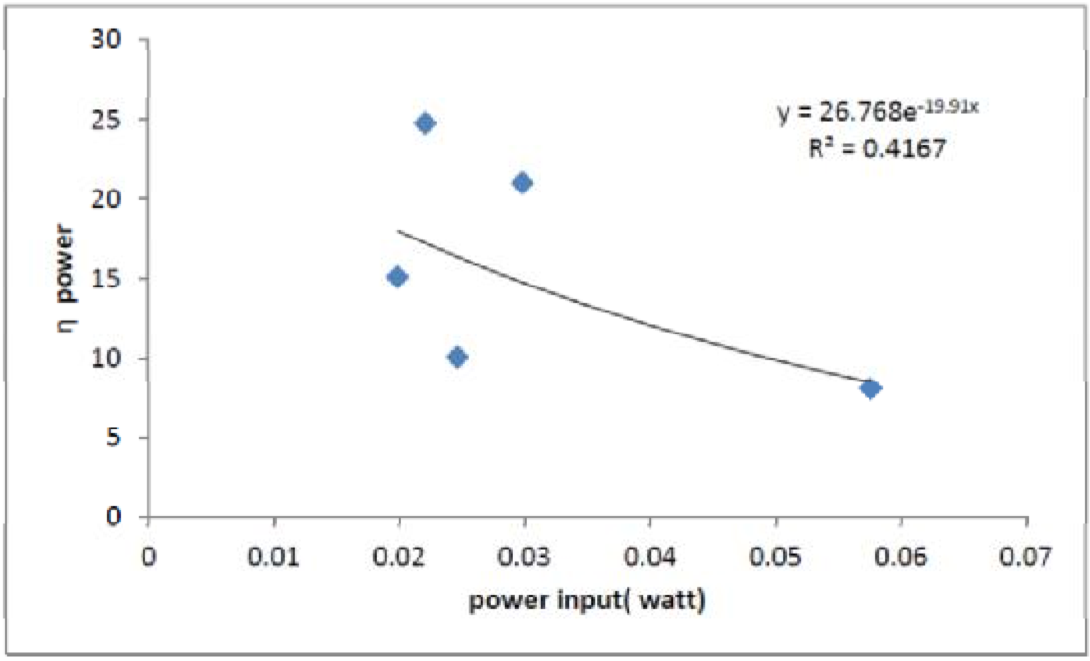


Figure (3.19)

The values of efficiency of flow versus input flow of abnormal for right side of heart.

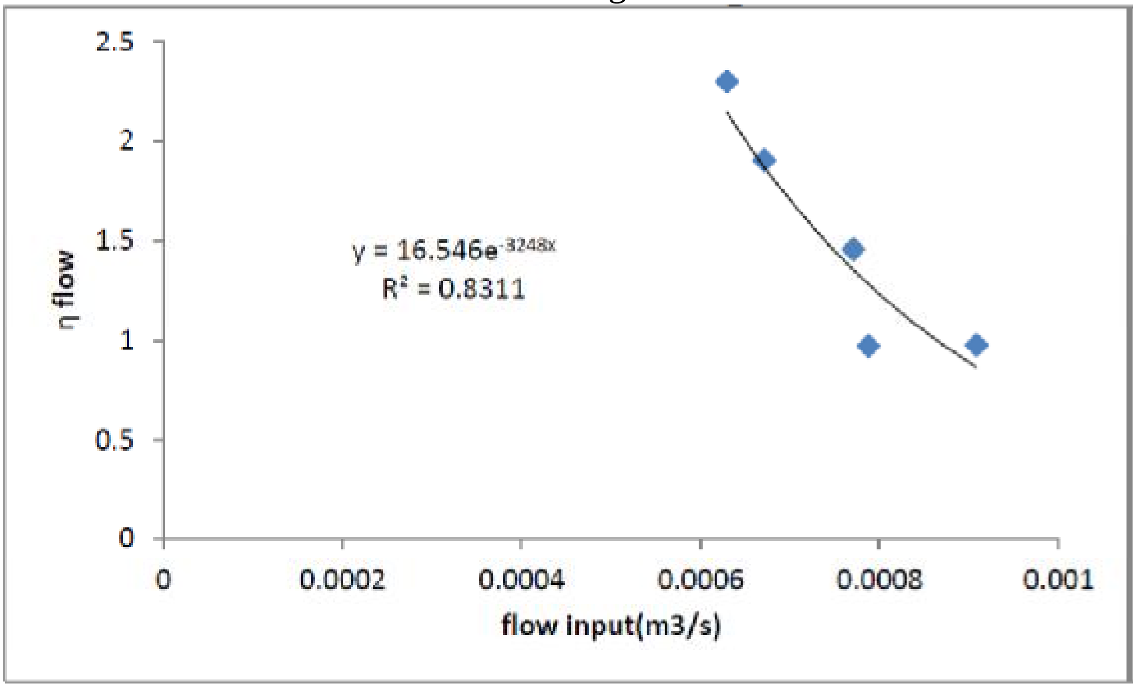
10. Figure (3.20) shows values of efficiency of power versus input power for the heart as a whole for abnormal. Values of start point for abnormal 26.77 but for normal 47.76 the same of R for normal and abnormal.



Figure(3.20)

The values of efficiency of power versus input power for the heart as a whole for abnormal.

11. Figure (3.21) shows values of efficiency of flow versus input flow for a whole of the heart with values of start point of higher than that of normal 16.55 while R value is also higher than that of normal.



Figure(3.21)

The values of efficiency of flow versus input flow for a whole of the heart for abnormal.

Chapter Four
Discussion and Conclusion

4.1 Discussion.

This project was built upon an important creature, the man who was subjected to this study, the main variables written above (power, flow and efficiency), were taken in consideration and because of a lack (shortage) of studies on human beings, many studies were done on a small sections of human function or on either animals or infants.

Poor studies on heart parts or on the heart as a whole ……

In general our study which was completely mechanical, or (physical aspect) and was concentrated on motion (movement, velocity, pressure, time and power), and a uniform increase in power and flow of each part of normal subjects was noticed for all subjects and in all figures of the three parts of the heart, the same was noticed by others studies (Husiman et al 1980, Chirinos et al 2012) but they noticed their notes on rats and dogs.

(Muller-Strahl at al 2002) study was also in accordance of our study, M.Kluckow and Evan 2000 also noticed the increase in infants flow but they didn't took power in consideration.

Muller-Strahl at al 2002 found the decrease in efficiency which was similar in our study for all the parts of the heart in input and output of right side, left side of the heart or for the heart as a whole. Namheaon Lee et al 1966 found the decrease in efficiency, but they took in consideration other variables like performance distance and stroke volume.

All figures (figures of power versus flow) drawn their R value is between R value = 0.5 but for most is 0.88 either for the left side or right side of the heart or for the heart as a whole.

Pepine et al 1976 studied the impedance, pulsatile pressure and flow, they studied the versus the age.

Kluckow and Evans 2000 studied the flow by Doppler echocardiography, the studied the flow versus the vascular resistance and versus the mean pressure.

When studying the input power versus output power and input flow versus output flow between each part of the heart a slight difference was noticed with a slight R value ≈0.006 the line approximately constant which means that there isn't any difference between them and the value of difference between them was so little (a very slight increment) between input and output of power and flow (the slope was too little). Poor previous studies for this point of view, and for the two side of the heart or for the heart as a whole.

Finally the trend of the efficiency of the heart was noticed to decrease either by flow or by power , the decrease was exponentially with R values were between 0.77 to 0.82 for the right side.

The same trend was for the left side and R values between 0.36 to 0.41 while for the heart as a whole is the R value are between 0.77 to 0.856. This was in accordance with for the efficiency another trend line which was linear, it Muller-Strahl et al 2002 and Numaheon Lee et al 1966 gave the same trend in inversely proportional but the exponential trend was more reasonable that of linear.

There was an accordance of this study with the study of Roberto M.Lang et al 2015, the dependence of flow and other activities of four chambers of the heart, but the other activities were not identified such as quantification and recommendation by echocardiography but the accordance was not, will defined by other activities.

Hidekatsu Fukuta and William C. Little 2008 found that time plays an important part for filling ventricles and with the way of contraction while filling which is quite clear in this study the change of heart activity after filling with the time of filling but it was fixed for one second.

Sandor J Kovacs 2015 was ready to call the heart is a pump which was considered in this study as a mechanical pump, and the mechanical efficiency was studiedfor the parts of this pump.

4.2 The comparison of abnormals in this study.

All normal cases showed that a linear increase for all cases to each orifice(inlet and outlet) when the figure was drawn to power versus flow with their R value in the figure but for abnormals the trend was different in superior and inferior vena cava figure 3.11.

Other studies of abnormals showed linearity but the mathematical model gave the trend the distance different from values of normal to explain the exerted by the heart muscle.

See figure 3.1.a and b with figure 3.11.

The constancy of power versus power and flow versus flow for normals to input and output values of right side orifice or the heart as a whole but for abnormals gave a positive linear power output versus input power but a negative linear slope for output and input flow for abnormals. (figures 3.13 and 3.14), (figures 3.16 and 3.17).

No influence was noticed at the aortic value because the same trend for normals and abnormals.

To compare efficiency with normals and abnormals for right side and the heart as a whole, the efficiency power to power for the two parts either right side or the heart as a whole, than abnormals while flow efficiency for abnormals was higher than normal.

4.3 Future study.

If more cases were studied, good measurement and more exact comparison were done, this helps to compare normal with abnormal values of the heart , and to diagnose and finally to compare results with Arab case instead of comparing them with people of manufacturing country.

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Appendix

Appendix (I)

A **correlation coefficient**

A correlation coefficient is a coefficient that illustrates a quantitative measure of some type of correlation and dependence, meaning statistical relationships between two or more random variables or observed data values.

R is calculated by the equation:

$$R = \frac{n(\sum X_i Y_i) - (\sum X_i)(\sum Y_i)}{\sqrt{n(\sum {X_i}^2) - (\sum X_i)^2}\sqrt{n(\sum {Y_i}^2) - (\sum Y_i)^2}}$$

Where :

R is correlation coefficient.

n is number of cases :

- For normal cases $n = 45$ case.
- But abnormal $n = 5$ case.

X_i is Values on the x-axis.

Y_i is Values on the y-axis.

Appendix_A

	right side								left side			
	input (SVC+IVC)						output-pulmonary		input-veins		output-aorta	
	P(watt)	Q(m3/s)	P(watt)	Q(m3/s)	P(SVC+IVC)	Q(SVC+IVC)	P(watt)	Q(m3/s)	P(watt)	Q(m3/s)	P(watt)	Q(m3/s)
	0.006312	0.00043	0.015796	0.000241	0.022108	0.000671	0.440807	0.001123	1.763226	0.004491	0.547781	0.001278
	0.012512	0.000407	0.011748	0.000172	0.024259	0.00058	0.318203	0.000851	1.27281	0.003404	0.330467	0.000825
	0.006447	0.000402	0.021215	0.000407	0.027662	0.00081	0.327076	0.001065	1.308303	0.004259	0.444249	0.001109
	0.009284	0.000579	0.01538	0.000329	0.024664	0.000908	0.190393	0.000713	0.761571	0.002851	0.248198	0.000885
	0.028335	0.000386	0.009401	0.000227	0.037736	0.000613	0.249827	0.000779	0.999309	0.003118	0.286563	0.000855
	0.0119	0.000198	0.004964	0.000169	0.016864	0.000367	0.206576	0.000859	0.826304	0.003437	0.38855	0.00111
	0.01224	0.000204	0.008115	0.000117	0.020355	0.000321	0.229106	0.000817	0.916423	0.003268	0.444295	0.001232
	0.006978	0.000402	0.021501	0.000316	0.028479	0.000718	0.474612	0.001247	1.898449	0.004988	0.47944	0.001217
	0.004189	0.000285	0.009219	0.000177	0.013408	0.000462	0.510116	0.001232	2.040465	0.004929	0.6344	0.001484
	0.010577	0.000198	0.004083	0.000161	0.014661	0.000359	0.229176	0.000817	0.916705	0.003269	0.294991	0.00088
	0.028206	0.000352	0.020508	0.000295	0.048714	0.000647	0.228471	0.000815	0.913885	0.003259	0.435183	0.001018
	0.029254	0.000456	0.023935	0.000326	0.053189	0.000782	0.215923	0.000851	0.863693	0.003404	0.422755	0.001021
	0.005236	0.000112	0.004319	0.000129	0.009555	0.000241	0.307087	0.001095	1.22835	0.00438	0.535307	0.001293
	0.015299	0.000255	0.006047	0.000129	0.021346	0.000384	0.326387	0.000815	1.305549	0.003259	0.431467	0.000964
	0.01054	0.000255	0.006232	0.000161	0.016772	0.000415	0.313963	0.001069	1.255853	0.004274	0.598285	0.001445
	0.013012	0.000314	0.015583	0.000212	0.028595	0.000526	0.822013	0.00181	3.288051	0.007241	1.298561	0.002161
	0.0085	0.000255	0.00677	0.000145	0.015269	0.000399	0.282063	0.001006	1.128253	0.004023	0.509961	0.001317
	0.006611	0.000141	0.003542	0.000106	0.010152	0.000248	0.305422	0.00104	1.221686	0.004158	0.690719	0.001521
	0.01591	0.00034	0.01182	0.000161	0.02773	0.000501	0.228337	0.000684	0.913347	0.002736	0.402299	0.001021
	0.039107	0.000532	0.018456	0.000238	0.057563	0.000771	0.33684	0.000885	1.34736	0.00354	0.464796	0.001123
	0.020987	0.000491	0.008865	0.000138	0.029852	0.000629	0.402601	0.00104	1.610404	0.004158	0.627234	0.001445
	0.018318	0.000416	0.028626	0.00039	0.046944	0.000805	0.409542	0.00104	1.63817	0.004158	0.548512	0.001369
	0.022716	0.000415	0.007898	0.000169	0.030614	0.000584	0.288309	0.000815	1.153235	0.003259	0.568598	0.001078
	0.013174	0.000219	0.005373	0.000161	0.018547	0.00038	0.295914	0.000943	1.183658	0.003771	0.342505	0.001006
	0.017891	0.000432	0.002262	0.000154	0.020154	0.000586	0.238671	0.000794	0.954683	0.003177	0.422755	0.001021
	0.025184	0.000377	0.008811	0.000161	0.033995	0.000538	0.272745	0.001021	1.09098	0.004084	0.575795	0.001135
	0.016252	0.00038	0.00371	6.78E-05	0.019963	0.000448	0.462382	0.001358	1.849528	0.005431	0.646657	0.00167
	0.017982	0.000264	0.006941	0.000149	0.024923	0.000413	0.234633	0.000817	0.938532	0.003269	0.416484	0.00104
	0.01182	0.000277	0.020015	0.000272	0.031835	0.000549	0.256459	0.000817	1.025837	0.003269	0.440556	0.001031

	0.005587	0.000167	0.009255	0.000154	0.014842	0.000321	0.239895	0.000733	0.959579	0.002933	0.36366	0.000908
	0.010493	0.000314	0.005319	8.85E-05	0.015812	0.000403	0.324876	0.000943	1.299505	0.003771	0.501169	0.001317
	0.012693	0.000634	0.007198	0.000154	0.019891	0.000788	0.178103	0.000523	0.712411	0.002092	0.300888	0.000764
	0.011667	0.00025	0.005183	9.24E-05	0.01685	0.000342	0.328835	0.000794	1.315341	0.003177	0.463809	0.001069
	0.027304	0.000426	0.0068	0.000204	0.034103	0.00063	0.235724	0.000905	0.942897	0.003621	0.550275	0.001194
	0.009996	0.000214	0.005508	8.59E-05	0.015503	0.0003	0.156021	0.000531	0.624085	0.002124	0.385545	0.000916
	0.014053	0.000339	0.017655	0.000228	0.031708	0.000567	0.402242	0.001141	1.608969	0.004563	0.544368	0.001278
	0.01432	0.000275	0.008328	0.000201	0.022648	0.000476	0.236563	0.000723	0.946251	0.002892	0.669094	0.001018
	0.011475	0.000191	0.005168	0.000204	0.016642	0.000395	0.21054	0.00083	0.84216	0.003319	0.306358	0.000893
	0.036265	0.000453	0.012947	0.000285	0.049212	0.000738	0.174678	0.000727	0.698711	0.002907	0.503181	0.001018
	0.016727	0.000305	0.007522	0.000225	0.024249	0.000531	0.316528	0.001247	1.266111	0.00499	0.578985	0.001521
	0.014851	0.000285	0.010326	0.000249	0.025177	0.000535	0.296989	0.000908	1.187956	0.003631	0.544818	0.001383
	0.005434	0.000131	0.017655	0.000228	0.023089	0.000359	0.186376	0.000851	0.745503	0.003404	0.327294	0.000908
avg	0.015134	0.000328	0.021428	0.000394	0.051697	0.001049	0.604334	0.001861	1.208669	0.003721	0.488495	0.00116
sum	0.635637	0.013759	0.449997	0.00828	1.085634	0.022039	12.69102	0.039071	50.7641	0.156282	20.51681	0.048739
st.d	0.008279	0.00012	0.006397	7.89E-05	0.011423	0.000169	0.117208	0.000228	0.468832	0.000913	0.168847	0.000267
var	6.85E-05	1.44E-08	4.09E-05	6.23E-09	0.00013	2.84E-08	0.013738	5.21E-08	0.219803	8.34E-07	0.028509	7.13E-08
t.tst	2.36618E-14		3.17466E-13		2.01613E-17		1.14522E-19		1.14522E-19		1.71125E-21	

Appendix B

The right side						The left side						a whole of heart	
P.S+P.I	**Q.S+Q.I**	**power(watt)**	**flow(m3/s)**	**η(power)**	**η(flow)**	**P2**	**Q2**	**power(watt)**	**flow(m3/s)**	**η (power)**	**η (flow)**	**η (power)**	**η (flow)**
0.022108	0.000671	0.547781	0.001278	24.77796	1.904174	1.763226	0.004491	0.547781	0.001278	0.31067	0.284539	24.77796	1.904174
0.024259	0.00058	0.330467	0.000825	13.62221	1.422593	1.27281	0.003404	0.330467	0.000825	0.259636	0.242327	13.62221	1.422593
0.027662	0.00081	0.444249	0.001109	16.05972	1.369565	1.308303	0.004259	0.444249	0.001109	0.339562	0.260331	16.05972	1.369565
0.024664	0.000908	0.248198	0.000885	10.06329	0.974292	0.761571	0.002851	0.248198	0.000885	0.325903	0.310384	10.06329	0.974292
0.037736	0.000613	0.286563	0.000855	7.593836	1.394942	0.999309	0.003118	0.286563	0.000855	0.286761	0.274193	7.593836	1.394942
0.016864	0.000367	0.38855	0.00111	23.04039	3.026036	0.826304	0.003437	0.38855	0.00111	0.470226	0.323056	23.04039	3.026036
0.020355	0.000321	0.444295	0.001232	21.82779	3.844279	0.916423	0.003268	0.444295	0.001232	0.484814	0.377078	21.82779	3.844279
0.028479	0.000718	0.47944	0.001217	16.83476	1.69579	1.898449	0.004988	0.47944	0.001217	0.252543	0.243982	16.83476	1.69579
0.013408	0.000462	0.6344	0.001484	47.3148	3.212185	2.040465	0.004929	0.6344	0.001484	0.31091	0.301194	47.3148	3.212185
0.014661	0.000359	0.294991	0.00088	20.12139	2.451841	0.916705	0.003269	0.294991	0.00088	0.321795	0.269231	20.12139	2.451841
0.048714	0.000647	0.435183	0.001018	8.933372	1.573121	0.913885	0.003259	0.435183	0.001018	0.47619	0.3125	8.933372	1.573121
0.053189	0.000782	0.422755	0.001021	7.948153	1.305449	0.863693	0.003404	0.422755	0.001021	0.489474	0.3	7.948153	1.305449
0.009555	0.000241	0.535307	0.001293	56.02443	5.356779	1.22835	0.00438	0.535307	0.001293	0.435794	0.295215	56.02443	5.356779
0.021346	0.000384	0.431467	0.000964	20.2129	2.511873	1.305549	0.003259	0.431467	0.000964	0.330487	0.295959	20.2129	2.511873
0.016772	0.000415	0.598285	0.001445	35.67195	3.478062	1.255853	0.004274	0.598285	0.001445	0.476397	0.338088	35.67195	3.478062
0.028595	0.000526	1.298561	0.002161	45.41284	4.104474	3.288051	0.007241	1.298561	0.002161	0.394933	0.298394	45.41284	4.104474
0.015269	0.000399	0.509961	0.001317	33.39807	3.296745	1.128253	0.004023	0.509961	0.001317	0.451992	0.327305	33.39807	3.296745
0.010152	0.000248	0.690719	0.001521	68.03514	6.146032	1.221686	0.004158	0.690719	0.001521	0.565382	0.365835	68.03514	6.146032
0.02773	0.000501	0.402299	0.001021	14.50776	2.036989	0.913347	0.002736	0.402299	0.001021	0.440466	0.373276	14.50776	2.036989
0.057563	0.000771	0.464796	0.001123	8.074614	1.456751	1.34736	0.00354	0.464796	0.001123	0.344968	0.317148	8.074614	1.456751
0.029852	0.000629	0.627234	0.001445	21.01167	2.296131	1.610404	0.004158	0.627234	0.001445	0.389488	0.347544	21.01167	2.296131
0.046944	0.000805	0.548512	0.001369	11.68429	1.699903	1.63817	0.004158	0.548512	0.001369	0.334832	0.329252	11.68429	1.699903
0.030614	0.000584	0.568598	0.001078	18.57317	1.8462	1.153235	0.003259	0.568598	0.001078	0.493046	0.330777	18.57317	1.8462
0.018547	0.00038	0.342505	0.001006	18.46676	2.645718	1.183658	0.003771	0.342505	0.001006	0.289362	0.266667	18.46676	2.645718
0.020154	0.000586	0.422755	0.001021	20.97657	1.74209	0.954683	0.003177	0.422755	0.001021	0.442822	0.321403	20.97657	1.74209
0.033995	0.000538	0.575795	0.001135	16.93748	2.108645	1.09098	0.004084	0.575795	0.001135	0.527778	0.277778	16.93748	2.108645
0.019963	0.000448	0.646657	0.00167	32.39357	3.726499	1.849528	0.005431	0.646657	0.00167	0.349633	0.307436	32.39357	3.726499

0.024923	0.000413	0.416484	0.00104	16.71088	2.52	0.938532	0.003269	0.416484	0.00104	0.443761	0.318029	16.71088	2.52
0.031835	0.000549	0.440556	0.001031	13.83875	1.877505	1.025837	0.003269	0.440556	0.001031	0.42946	0.315385	13.83875	1.877505
0.014842	0.000321	0.36366	0.000908	24.50226	2.824723	0.959579	0.002933	0.36366	0.000908	0.378979	0.309499	24.50226	2.824723
0.015812	0.000403	0.501169	0.001317	31.69483	3.268957	1.299505	0.003771	0.501169	0.001317	0.385661	0.349125	31.69483	3.268957
0.019891	0.000788	0.300888	0.000764	15.12661	0.969672	0.712411	0.002092	0.300888	0.000764	0.422352	0.365084	15.12661	0.969672
0.01685	0.000342	0.463809	0.001069	27.52522	3.124422	1.315341	0.003177	0.463809	0.001069	0.352615	0.33634	27.52522	3.124422
0.034103	0.00063	0.550275	0.001194	16.13546	1.896966	0.942897	0.003621	0.550275	0.001194	0.5836	0.329861	16.13546	1.896966
0.015503	0.0003	0.385545	0.000916	24.86842	3.057323	0.624085	0.002124	0.385545	0.000916	0.617777	0.431463	24.86842	3.057323
0.031708	0.000567	0.544368	0.001278	17.16837	2.252159	1.608969	0.004563	0.544368	0.001278	0.338333	0.28	17.16837	2.252159
0.022648	0.000476	0.669094	0.001018	29.54342	2.138897	0.946251	0.002892	0.669094	0.001018	0.7071	0.352113	29.54342	2.138897
0.016642	0.000395	0.306358	0.000893	18.4083	2.262044	0.84216	0.003319	0.306358	0.000893	0.363776	0.268939	18.4083	2.262044
0.049212	0.000738	0.503181	0.001018	10.22476	1.380369	0.698711	0.002907	0.503181	0.001018	0.720156	0.350346	10.22476	1.380369
0.024249	0.000531	0.578985	0.001521	23.87662	2.865939	1.266111	0.00499	0.578985	0.001521	0.457294	0.304863	23.87662	2.865939
0.025177	0.000535	0.544818	0.001383	21.63968	2.587018	1.187956	0.003631	0.544818	0.001383	0.458618	0.380886	21.63968	2.587018
0.023089	0.000359	0.327294	0.000908	14.1756	2.527124	0.745503	0.003404	0.327294	0.000908	0.439024	0.266666	14.1756	2.527124

Appendix C

ABNORMAL CASES									
SVC+IVC		pulmonary artery		AORTA		right side		a whole of heart	
P(SVC+IVC)	Q(SVC+IVC)	P(watt)	Q(m3/s)	P(watt)	Q(m3/s)	η(power)	η(flow)	η(power)	η(flow)
0.024664	0.000908	0.190393	0.000713	0.248198	0.000885	7.71955	0.784748	10.06329	0.974292
0.019891	0.000788	0.178103	0.000523	0.300888	0.000764	8.953788	0.664006	15.12661	0.969672
0.029852	0.000629	0.402601	0.00104	0.627234	0.001445	13.48671	1.651686	21.01167	2.296131
0.057563	0.000771	0.33684	0.000885	0.464796	0.001123	5.851715	1.148322	8.074614	1.456751
0.022108	0.000671	0.440807	0.001123	0.547781	0.001278	19.93916	1.673037	24.77796	1.904174

المعلومات الشخصية

الاسم: محمود عواد النعيمات

التخصص: ماجستير الفيزياء

الكلية: العلوم

السنة: 2015

هاتف رقم: 0777543034